FINAL

Feasibility Study Report
Site 07 - Calf Pasture Point
Naval Construction Battalion Center
Davisville, Rhode Island

Contract No. N62472-92-D-1296
Contract Task Order No. 32

Prepared for

Department of the Navy
Northern Division
Naval Facilities Engineering Command
10 Industrial Highway
Mail Stop No. 82
Lester, Pennsylvania 19113-2090

Prepared by

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September 1998 *29600.32.3495*

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10 September '98

James A. Shultz, CPG
CTO Manager
Date

4 Sep 98

Charles R. Flynn, Ph.D., PH
Program Manager
Date

September 1998

QUALITY REVIEW STATEMENT

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Activity Naval Construction Battalion Center, Davisville, Rhode Island

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Final- Feasibility Study Report, Site 07 - Calf Pasture Point, Naval Construction Battalion Center, Davisville, Rhode Island

EA CTO Manager: James Shultz

In compliance with EA's Quality Procedures for review of deliverables outlined in the Program Quality Management Plan, this final deliverable has been reviewed for quality by the undersigned Senior Technical Reviewer. The information presented in this report/deliverable has been prepared in accordance with the approved Implementation Plan for the Contract Task Order (CTO) and reflects a proper presentation of the data and/or the conclusions drawn and/or the analyses or design completed during the conduct of the work. This statement is based upon the standards identified in the CTO and/or the standard of care existing at the time of preparation.

Senior Technical Reviewer

Robert S. Palermo 9-9-98

Robert S. Palermo, Dr.S., LSP, CGWP, CEP Date

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LIST OF ACRONYMS AND ABBREVIATIONS

ACL	Alternate Concentration Limit
ARAR	Applicable or Relevant and Appropriate Requirement
AWQC	Ambient Water Quality Criteria
bgs	Below Ground Surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Chemical(s) of Concern
CRMC	Coastal Resources Management Council
CRMP	Coastal Resources Management Program
CS	Confirmation Study
CTO	Contract Task Order
CWA	Clean Water Act
CY	Cubic Yard(s)
DAA	Detailed Analysis of Alternatives
DANC	Decontaminating Agent Non-Corrosive
dB	Decibel(s)
1,2-DCA	1,2-Dichloroethane
1,2-DCE	1,2-Dichloroethene
DNAPL	Dense Non-Aqueous Phase Liquid
EA	EA Engineering, Science, and Technology, Inc.
EM	Electromagnetic conductivity
EPA	(United States) Environmental Protection Agency
ERA	Ecological Risk Assessment(s)
FID	Flame Ionization Detector
FS	Feasibility Study
FUDS	Formally Used Defense Site
GAC	Granular Activated Carbon
HDPE	High Density Polyethylene
HHRA	Human Health Risk Assessment
HI	Hazard Index
HMTA	Hazardous Materials Transportation Act
HQ	Hazard Quotient(s)
HRS	Hazard Ranking System
IAS	Initial Assessment Study
IR Program	Installation Restoration Program
ISA	Initial Screening of Alternatives
LDR	Land Disposal Restrictions
LEL	Lower Explosive Limit
LTT	Low Temperature Thermal (Treatment/Desorption)
MCL	Maximum Contaminant Level(s)
MCLG	Maximum Contaminant Level Goal(s)
MGD	Million Gallons per Day

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

msl	Mean Sea Level
MW07-#	Monitoring Well (Site 07) - (with designation)
NAAQS	National Ambient Air Quality Standards
NACIP	Navy Assessment and Control of Installation Pollutants
NARF	Naval Air Rework Facility
NAS	Naval Air Station
NBB	Narragansett Bay Basin
NCBC	Naval Construction Battalion Center
NCTC	Naval Construction Training Center
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NESHAP	National Emission Standard of Hazardous Air Pollutants
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NWI	National Wetlands Inventory
O&M	Operation and Maintenance
OSHA	Occupational Health and Safety Administration
OSWER	Office of Solid Waste and Emergency Response
PA	Preliminary Assessment
PAH	Polynuclear Aromatic Hydrocarbon(s)
1,1,2,2-PCA	1,1,2,2-Perchloroethane
PCB	Polychlorinated Biphenyl(s)
PCE	Perchloroethene
PEL	Permissible Exposure Limit
POTW	Publicly Owned Treatment Works
ppb	Parts Per Billion
PPE	Personal Protective Equipment
ppm	Parts Per Million
PRAP	Proposed Remedial Action Plan
PRG	Preliminary Remediation Goal(s)
QA/QC	Quality Assurance/Quality Control
RAO	Remedial Action Objective(s)
RAPS	Risk Assessment Pilot Study
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RI	Remedial Investigation
RIDEM	Rhode Island Department of Environmental Management
RIDoH	Rhode Island Department of Health
RIEDC	Rhode Island Economic Development Corporation
RIGL	Rhode Island General Law
RIPA	Rhode Island Port Authority
RIPDES	Rhode Island Pollutant Discharge Elimination System

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

RME	Reasonable Maximum Exposure
RO	Reverse Osmosis
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SEM/AVS	Simultaneously Extracted Metals/Acid Volatile Sulfide
SI	Site Inspection
SITE	Superfund Innovative Technology Evaluation
SMCL	Secondary Maximum Contaminant Level(s)
SVCA	Soil Vapor Contaminant Assessment
SVOC	Semivolatile Organic Compound(s)
TAL	Target Analyte List
TBC	To Be Considered
1,1,2-TCA	1,1,2-Trichloroethane
TCE	Trichloroethene
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
UCL	Upper Concentration Limit(s)
USACE	United States Army Corps of Engineers
USC	United States Code
USDA	United States Department of Agriculture
USGS	United States Geological Survey
VC	Vinyl Chloride
VOC	Volatile Organic Compound(s)
WQC	Water Quality Criteria

ABSTRACT

This Feasibility Study (FS) develops and evaluates whole-site remedial alternatives for Installation Restoration Program Site 07 (Calf Pasture Point) at the former Naval Construction Battalion Center (NCBC) located in Davisville, Rhode Island. The FS builds upon findings of a Phase I, II, and III Remedial Investigation (RI), a Human Health Risk Assessment (HHRA), and the Marine and Freshwater/Terrestrial Ecological Risk Assessments (ERA).

Site 07 is located on Calf Pasture Point, a peninsula in the northeastern portion of NCBC Davisville. Calf Pasture Point was reportedly the site of three distinct disposal incidents between 1960 and 1974. These incidents included (1) disposal of twenty 5-gallon cans of calcium hypochlorite (bleach) in a drainage ditch alongside Bunker 60 at Calf Pasture Point, (2) disposal of thirty to forty 35-gallon containers of an unidentified chloride compound, and (3) disposal of an estimated 2,500 3-gallon cans of "Decontaminating Agent Non-Corrosive" (DANC) solution in a trench measuring approximately 10 ft × 20 ft × 15 ft. The DANC solution consisted of two separate chemicals: 1,3-dichloro-5,5-dimethyl-hydantoin (a crystal); and 1,1,2,2-perchloroethane (1,1,2,2-PCA): a heavy, colorless liquid]. The investigations at Site 07 identified elevated levels of chlorinated volatile organic compounds (VOC) [primarily as 1,1,2,2-PCA and trichloroethene (TCE)] in shallow, deep, and bedrock ground water beneath the site.

There appears to be two plumes of chlorinated VOC in Site 07 ground water. The first plume is located in deep ground water in the vicinity of the DANC disposal area (i.e., near MW07-05D). This plume extends south toward the shoreline in deep and bedrock ground water. The second plume is located in shallow ground water in the southwestern portion of the site (between MW07-19S, 21S, and 26S) where there were no reported disposal activities. The second plume may be an extension of the plume in deep ground water due to the impact on ground-water flow from a salt water "wedge" located beneath the southern portion of the site. The 1,1,2,2-PCA appears to have migrated vertically downward from the former DANC disposal area through locally-present sandy facies of the underlying silt unit rather than laterally through the upper sand unit. Transport of VOC in the deeper unconsolidated layers appears to be partially influenced by an apparent valley in the bedrock topography in the vicinity of the DANC disposal area. Although no free-flowing Dense Non-Aqueous Phase Liquid (DNAPL) has been measured in the monitoring wells during the Phase I, II, or III RI, the chemical data suggest that residual 1,1,2,2-PCA and/or TCE DNAPL may be present in the vicinity of MW07-04D, MW07-05D, MW07-15D, and MW07-17D. If present, the original free-flowing DNAPL appears to have migrated vertically downward from the DANC disposal area through a sandy facies in the overlying silt unit into the till unit, migrated along a portion of the apparent valley in the bedrock surface, and down into bedrock fractures.

No Remedial Action Objectives were identified for surface or subsurface soil because no unacceptable terrestrial ecological or human health risks were identified onsite and because the regulatory criteria and/or background levels for NCBC Davisville were not exceeded. No Remedial Action Objectives were identified for offshore environmental media (e.g., shoreline

sediment) or potential offshore ecological receptors (e.g., shoreline shellfish) because (1) although there is a ground-water pathway from the site to offshore areas, no unacceptable human health risks have been identified from ground-water migration, (2) the Marine ERA indicated that a cause-and-effect relationship could not be established for potential risks to the marine ecology from Site 07, and (3) the low ecological risks identified along the shoreline have not been linked to Site 07 (i.e., these low risks are attributable to COC which were not related to Site 07). Remedial Action Objectives for ground water were developed to address the unacceptable risks identified during the HHRA and the COC that exceed regulatory criteria for ground water. The following hypothetical pathways were identified in the HHRA as presenting unacceptable risk:

- ingestion of deep and bedrock ground water by residential populations;
- inhalation of VOC from, and dermal contact with, deep and bedrock ground water while showering by recreational users;

The use of deep and bedrock ground water for drinking and showering are possible scenarios requested by EPA, but are not required for the planned use of the site as a conservation area. It is unlikely that ground water at Site 07 would be used as a drinking water source (or for showering) because (1) the aquifer at Site 07 has limited value as a potential drinking water source due to the high salinity identified beneath much of the site, (2) public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) the impacted portion of the aquifer at Calf Pasture Point was found to be low-yielding during the Navy's ground-water investigations. Additionally, the unacceptable exposure scenarios related to ground water were developed using data from the VOC plume area and not the entire site, thereby making them highly conservative (i.e., worst case).

Based upon the Remedial Action Objectives, the following potential remedial alternatives were developed for Site 07:

Alternative 1: No Action (nominal cost)

- 5-year reviews

Alternative 2: Deed Restriction and Long-Term Monitoring (estimated $1,679,000 total 30-year net present worth)

- Deed restriction prohibiting the future use of site ground water

- Long-term monitoring to ensure that the plume continues to pose no unacceptable risks

- 5-year reviews

Alternative 3: ***In-Situ*** **Anaerobic Biodegradation** (estimated $3,619,000 total 30-year net present worth)

- Deed restriction prohibiting the future use of site ground water
- Installation of injection wells to be used to inject a substrate that would promote the anaerobic biodegradation of chlorinated VOC within portions of the plume
- Long-term monitoring to evaluate the effectiveness of assisted biodegradation and to ensure that the plume continues to pose no unacceptable risks
- 5-year reviews

Alternative 4: Vacuum-Vaporizer-Wells (estimated $5,867,000 total 30-year net present worth)

- Deed restriction prohibiting the future use of site ground water
- Installation and operation of Vacuum-Vaporizer Well systems to treat the ground-water source areas
- Treatment of offgas from Vacuum-Vaporizer Wells
- Long-term monitoring to evaluate the effectiveness of the system and to ensure that the plume continues to pose no unacceptable risks
- 5-year reviews

Alternative 5: ***In-Situ*** **Permeable Reaction Wall** (estimated $9,062,000 total 30-year net present worth)

- Deed restriction prohibiting the future use of site ground water
- Installation of an *in-situ* sheet pile walls to channel impacted shallow and deep ground water through a permeable, reactive wall that will promote the degradation of most chlorinated COC
- Long-term monitoring to evaluate the effectiveness of the system for reducing chlorinated VOC concentrations migrating offsite via shallow/deep ground water and to ensure that the plume continues to pose no unacceptable risks
- 5-year reviews

Subsequent to this FS, the Navy will present their preferred remedial alternative for public comment in a Proposed Plan. The selected remedial alternative will be presented in the Record of Decision to be signed by the Navy and EPA Region I, with concurrence by the Rhode Island Department of Environmental Management. The Record of Decision for Site 07 also will include the "Calf Pasture Point Munitions Bunkers" Study Area which was investigated under a separate Study Area Screening Evaluation and Close-Out Report.

EXECUTIVE SUMMARY

This Feasibility Study (FS) has been prepared by EA Engineering, Science, and Technology (EA) in accordance with the Scope of Work for Contract Task Order (CTO) 0032, Contract N62472-92-D-1296. The FS develops and evaluates whole-site remedy remedial alternatives for Installation Restoration (IR) Program Site 07 (Calf Pasture Point) at the former Naval Construction Battalion Center (NCBC) located in Davisville, Rhode Island. The FS builds upon findings of the Phase I, II, and III Remedial Investigations (RI), the Human Health Risk Assessment (HHRA), and the Marine and Freshwater/Terrestrial Ecological Risk Assessments (ERA) completed for Site 07 and Allen Harbor. The Record of Decision (ROD) for Site 07 will include the "Calf Pasture Point Munitions Bunkers" Study Area; the results of this investigation are being presented under a separate Study Area Screening Evaluation (Haliburton NUS 1994) and Close-Out Report (Foster Wheeler 1997).

This FS has been conducted under the Navy's IR Program in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. The U.S. Environmental Protection Agency (EPA) document "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA - Interim Final" (EPA 1988) was used as the guidance document for preparation of this report. NCBC Davisville is currently listed as a Superfund site on the National Priorities List (NPL).

NCBC DAVISVILLE

NCBC Davisville is located in the Town of North Kingstown, Rhode Island, approximately 18 miles south of the state capital, Providence. NCBC Davisville was composed of three areas: the Main Center (Zones 1 through 4), the West Davisville storage area, and Camp Fogarty—a training facility located approximately 4 miles west of the Main Center. Camp Fogarty was transferred to the U.S. Department of the Army in December 1993 and is assigned to the Rhode Island National Guard. Adjoining the southern boundary of the Main Center is the decommissioned Naval Air Station (NAS) Quonset Point, which was transferred by the Navy to the Rhode Island Port Authority (RIPA) [currently named the Rhode Island Economic Development Corporation (RIEDC)] and others between 1975 and 1980.

NCBC Davisville was primarily used for training naval seamen in construction operations, and as storage and freight yards for construction materials. As a result, NCBC Davisville is comprised primarily of warehouse space and freight yards, most of which are currently empty. NCBC Davisville closed on 1 April 1994. Most of the staff and materials have been moved offsite. Currently, facilities management and security staff engaged with base closure remain on base.

SITE 07 - CALF PASTURE POINT

Site 07 is located on Calf Pasture Point, a peninsula in the northeastern portion of NCBC Davisville. The Phase III RI study area covered approximately 40 acres of Calf Pasture Point. Prior to 1940, the central portion of the Calf Pasture Point peninsula was a portion of Allen Harbor. During the 1942/1943 dredging activity by the Navy for the pier area along the Narragansett Bay Shoreline south of Site 07, dredge material was placed at Calf Pasture Point, thereby filling in the shallow lagoon. Allen Harbor was also dredged and the material was likely placed in Calf Pasture Point lagoons as well as joining the island to the south to form what is now known as Spink Neck.

Calf Pasture Point is bounded to the southwest and south by Allen Harbor and its entrance channel, respectively; to the east by Narragansett Bay, and to the west and north by Sanford Road. Calf Pasture Point contains three former munitions bunkers (Buildings 59, 60, and 339) located along Magazine Road. The bunkers are earthen covered and are located in the middle of Calf Pasture Point just north, east, and south of the bedrock outcrop [a prominent hill with a maximum elevation of approximately 55 ft above mean sea level (MSL)—the highest location at Calf Pasture Point]. Calf Pasture Point is currently overgrown with shrubs, small trees, grasses, and reeds. During late 1996/early 1997, the Navy cleaned the bunkers, demolished Bunker 339, and welded the doors shut to Bunkers 59 and 60.

PAST DISPOSAL ACTIVITIES

Calf Pasture Point was reportedly the site of three distinct disposal incidents between 1960 and 1974. These incidents included (1) disposal of twenty 5-gallon cans of calcium hypochlorite (bleach) in a drainage ditch alongside Bunker 60 at Calf Pasture Point, (2) disposal of thirty to forty 35-gallon containers of an unidentified chloride compound, and (3) disposal of an estimated 2,500 3-gallon cans of "Decontaminating Agent Non-Corrosive" (DANC) solution in a trench measuring approximately 10 ft × 20 ft × 15 ft. The DANC solution consisted of two separate chemicals: 1,3-dichloro-5,5-dimethyl-hydantoin (a crystal); and 1,1,2,2-perchloroethane [(1,1,2,2-PCA): a heavy, colorless liquid].

PREVIOUS INVESTIGATIONS PERFORMED AT SITE 07

Several investigations have been performed at NCBC Davisville in conjunction with the Navy, the Rhode Island Department of Environmental Management (RIDEM), and the EPA. The primary Navy investigation reports that pertain to characterization of Site 07, in chronological order, include the following:

- Initial Assessment Study, Fred C. Hart 1984
- Confirmation Study - Verification Step Report, TRC 1987
- Confirmation Study - Characterization Step Report, TRC 1988
- Phase I RI Report, TRC 1991
- Phase II RI Report, TRC 1994

- Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment Report, EA 1996a
- Draft Final Allen Harbor Landfill and Calf Pasture Point Marine Ecological Risk Assessment Report, SAIC 1996b
- Phase III RI Report, EA 1998a
- Human Health Risk Assessment, EA 1998a

RESULTS OF THE REMEDIAL INVESTIGATIONS

Phase I RI (1991)

The Phase I RI included two soil borings/monitoring wells (MW07-3S and MW07-4S) located downgradient of a magnetic anomaly identified during the Confirmation Study and the collection of soil samples from the two borings and ground-water samples from three wells (MW07-1S, MW07-3S, and MW07-4S). Estimated concentrations of chloroform, 4,4'-DDT, and 4,4'-DDE were reported in one of the surface soil samples (B7-1), while an estimated concentration of bis(2-ethylhexyl)phthalate [220 J micrograms per kilogram (μg/kg)] was reported from the 2 to 4 ft interval below ground surface (bgs) sample from boring B7-2. The compound 1,1,2,2-PCA was not detected in soil or ground-water samples; however, two potential degradation products of 1,1,2,2-PCA [1,2-dichloroethene (1,2-DCE) and vinyl chloride (VC)] were detected in the ground-water samples at estimated concentrations of 30 micrograms per liter (μg/L) and 2 μg/L, respectively. Metals found to be common to each surface and subsurface soil sampling location included arsenic, chromium, lead, and zinc. No depth-specific differences were observed in either the presence or concentration of these metals. Antimony and copper were detected in the ground-water samples. Toxicity Characteristic Leaching Procedure (TCLP) results reported that a low concentration of toluene may be leachable from the soil. TCLP extraction results also reported that copper, lead, and zinc were leachable from the soils. Polychlorinated biphenyls (PCB) were not detected in soil, ground water, or sediment. The Phase I RI recommended no further remedial action with bi-annual ground-water monitoring for Site 07.

Phase II RI (1994)

Geophysical investigations comprised of a seismic refraction survey, an electromagnetic conductivity (EM) survey, and a magnetometer survey, were performed to gain a better understanding of the subsurface at the Calf Pasture Point prior to drilling for the Phase II RI. The seismic refraction survey was primarily used to profile the bedrock surface below portions of the site. The EM survey was used to aid in assessing the location and/or extent of buried metallic objects (e.g., drums, tanks, metal structures), or conductive ground water. The magnetometer survey aided in distinguishing anomalies due to ferrous metal from electrically conductive, EM-identified, non-ferrous objects. The Phase II RI included:

A soil gas survey was performed at thirty points in an area located just east of Bunker No. 339, and between Bunker No. 60 and wells MW07-1S, MW07-2S, and MW07-3S.

Volatile organic compounds (VOC) were detected at one sample location east of Bunker 339 at a total concentration of 12 μg/L [as "total Flame Ionization Detector (FID) VOC"]. Results of the soil gas survey provided the rational for moving a planned surface soil sampling location 07SS-8 to investigate an elevated VOC soil gas sample location.

Four seismic refraction geophysical survey lines were performed in the vicinity of the three bunkers and south to the vicinity of wells MW07-3S, MW07-4S, and MW07-5S (plus a line about 400 ft east of MW07-5S and one line south). The interpreted depth to the competent bedrock surface was estimated to range between 14 to 26 ft bgs and to be sloping downward from the north to the south. An assessment of the extent and thickness of highly fractured or highly weathered bedrock was unsuccessful because the refraction velocities through this zone could not be distinguished from that of the saturated soil. Therefore, only the top of competent bedrock could be identified.

An EM survey was performed on approximately 9.2 acres extending as far north as the bedrock outcrop and as far south as the marshlands, on a 50-ft grid using a Geonics EM-31 instrument. A small electrically conductive area was recorded near MW07-2S, corresponding to the area of buried drums discovered during the Confirmation Study. The EM values ranged from 3.0 mmhos/meter in the northwest portion of the site to 68 mmhos/meter in the southeast. This gradual change in EM values was attributed to salt water intrusion into the ground water.

A magnetometer survey was performed along the same field location grid used for the EM survey. One of the anomalies identified during the CS was located (the same anomaly also identified by the EM survey). A test pit was planned at this location between MW07-2S and MW07-1S. Magnetometer values recorded during the survey were used to produce a magnetic contour map of the site. The magnetometer contour map indicated areas of elevated or depressed magnetometer values (with respect to background) across the site. Based on the EM and magnetometer surveys, one of the planned test pits (TR-04) was relocated to investigate the magnetic anomaly located adjacent to MW07-2S.

Four test pit investigations were conducted, including soil sampling, to visually inspect three areas where geophysical anomalies were mapped. Test pit 1 was located adjacent to MW07-8S, test pit 2 was located adjacent to MW07-6S, test pit 3 was located adjacent to MW07-3D, and test pit 4 was located between MW07-1 and MW07-5. At three test pit locations, no evidence of soil contamination was detected. At the fourth location (TP-02), no evidence of soil contamination could be identified but the source of the geophysical anomaly could be attributed to a short length of buried metal pipe about 0.5 ft bgs, also believed to be the source of the Confirmation Study anomaly. Low concentrations of metals were detected in the test pit samples.

Four shallow borings/wells (MW07-5S, MW07-6S, MW07-7S, and MW07-8S) and two deep borings/wells (MW07-3D and MW07-5D) were installed and surface and subsurface soil samples were analyzed. Acetone (non-detect to 52 μg/kg) and 1,1,1-trichloroethane (non-detect to 3 J μg/kg) were detected in subsurface soil. Various metals were detected in surface and subsurface soils.

VOC were detected in both shallow and deep ground water. 1,2-DCE and trichloroethene (TCE) were detected in 4 of 9 ground-water monitoring wells; 1,1,2,2-PCA was detected in 3 of the 9 wells which were sampled. In deep and shallow ground water, the highest total VOC concentration reported was 57,400 μg/L (MW07-5D) and 37 μg/L (MW07-2S), respectively.

Supplemental Phase II RI (1994)

The objectives were to locate the original source area of the chlorinated-VOC in ground water as well as the horizontal extent of VOC in the downgradient deep ground water.

Twenty-one micro-wells were installed and sampled in the general area between MW07-7S, MW07-1S, and MW07-2S to assess the source area for the chlorinated solvent (i.e., DANC) disposal/release. Results of the micro-well ground-water samples were used to delineate the extent of VOC in shallow ground water in the suspected disposal/release area. The highest VOC concentrations were detected in micro-wells GH-2 and GH-7 at total VOC concentrations of 776 μg/L and 318 J μg/L, respectively. These two micro-wells are located north of well MW07-2S and just south and north of the dirt road, respectively.

Five deep monitoring wells (MW07-9D through MW07-13D) were installed in the area south of wells MW07-4S and MW07-3S toward the shoreline. These wells were drilled to refusal (bedrock was not confirmed by coring).

Based upon the results of the micro-wells, the source area for the chlorinated-VOC in ground-water samples appeared to be approximately 30 to 80 ft north of well MW07-2S. A relatively small plume of dissolved chlorinated-VOC was detected in samples from wells MW07-2S and MW07-4S. Chlorinated VOC were detected in ground-water samples collected from each of the five deep wells with the highest total concentration detected in the sample collected from well MW07-9D at 5,860 μg/L. Maximum concentrations of VOC which were detected include acetone at 57 μg/L (MW07-12D), 1,2-DCE (total) at 2,800 μg/L (MW07-9D), TCE at 1,500 μg/L (MW07-9D), 1,1,2-trichloroethane (1,1,2-TCA) at 270 μg/L (MW07-9D), benzene at 40 J μg/L (MW07-10D), and 1,1,2,2-PCA at 1,300 μg/L (MW07-9D). Various metals were also detected in ground water.

Phase III RI (1998a)

The Phase III RI further assessed the nature and extent of Target Compound List - Volatile Organic Compounds (TCL-VOC) and Target Analyte List (TAL) metals in ground water as well as the behavior/migration of VOC and metals from beneath Site 07 to Allen Harbor and Narragansett Bay. The results of the study are summarized below:

- VOC in Soil: Chlorinated VOC were detected in the northern portion of the site (MW07-04, MW07-14, and MW07-17) in soil samples from the upper sand unit. The highest concentration of total chlorinated VOC were detected in a sample from MW07-14 in the vicinity of the disposal area. Three chlorinated VOC were detected in that sample: 1,1,2,2-PCA at 38,000 μg/kg, TCE at 1,200 μg/kg, and perchloroethene (PCE) at 310 μg/kg. The highest concentration of chlorinated VOC were detected in the silt underlying the upper sand unit in samples from the northern portion of the site (MW07-04, MW07-05, MW07-14, and SB07-02). The concentrations of total chlorinated VOC in four samples from that area ranged from 16,390 μg/kg to 52,000 μg/kg, and were collected from depths of 22 to 41 ft below ground surface. TCE and 1,1,2,2-PCA were the primary VOC detected in these four samples. Chlorinated VOC were also detected in the lower sand and till units in the northern portion of the site extending to the southwest. The higher concentrations of total chlorinated VOC were detected in four samples from the vicinity of the former DANC disposal area (MW07-05, SB07-01, MW07-31, and MW07-17). The concentrations of total chlorinated VOC in these four samples ranged from 12,960 μg/kg to 48,400 μg/kg.

- VOC in Ground Water: There appears to be two plumes of chlorinated VOC in Site 07 ground water. The first plume is located in deep ground water in the vicinity of the DANC disposal area (i.e., near MW07-05D). This plume extends south toward the shoreline in deep and bedrock ground water. The second plume is located in shallow ground water in the southwestern portion of the site (between MW07-19S, 21S, and 26S) where there were no reported disposal activities. The second plume may be an extension of the plume in deep ground water due to the impact on ground-water flow from a salt water "wedge" located beneath the southern portion of the site. 1,1,2,2-PCA (a major component of DANC) appears to have migrated vertically downward from the former DANC disposal area through locally-present sandy facies of the underlying silt unit rather than laterally through the upper sand unit. Transport of VOC in the deeper unconsolidated layers appears to be partially influenced by an apparent valley in the bedrock topography in the vicinity of the DANC disposal area. Although no free-flowing Dense Non-Aqueous Phase Liquid (DNAPL) has been measured in the monitoring wells during the Phase I, II, or III RI, the chemical data suggest that residual 1,1,2,2-PCA and/or TCE DNAPL may be present in the vicinity of MW07-04D, MW07-05D, MW07-15D, and MW07-17D. If present, the original free-flowing DNAPL appears to have migrated vertically downward from the DANC disposal area through a sandy facies in the overlying silt unit into the till unit, migrated along a portion of the apparent valley in the bedrock surface, and down into bedrock fractures.

- Metals in Ground Water: Only thallium exceeded its Safe Drinking Water Act (SDWA) Maximum Contaminant Level (MCL) and iron and manganese were detected above their respective, non-enforceable, Secondary Maximum Contaminant Levels (SMCL). Iron and manganese were generally below NCBC background levels and the thallium concentrations were below the concentrations detected in the water samples from Allen Harbor and Narragansett Bay.

- Ground-Water Impact on Surface Water: Although a ground-water pathway exists from the site to Allen Harbor and Narragansett Bay, no adverse impacts or unacceptable risks have been identified in surface water due to the conditions at Site 07.

- Ground-Water Impact on Adjacent Intertidal Sediment: Although a ground-water pathway exists from the site to offshore sediment, no unacceptable risks have been identified in offshore sediment due to the conditions at Site 07.

The Phase III RI recommended no further action with long-term monitoring.

RESULTS OF HUMAN HEALTH RISK ASSESSMENT

Cancer risks [greater than one-in-one million ($>10^{-6}$)] to human health from chemical concentrations in ground water were associated with the hypothetical exposures resulting from the ingestion of deep and bedrock ground water by potential residential populations [due to concentrations of arsenic and VOC, including benzene, chloroform, 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE), PCE, 1,1,2,2-PCA, 1,1,2-TCA, TCE, and VC] and the inhalation/dermal contact by recreational populations with deep and bedrock ground water while showering (primarily from concentrations of 1,1,2,2-PCA, TCE, VC, 1,1,2-TCA, 1,2-DCA, 1,1-DCE, chloroform, and benzene). Cancer risks (risk $> 10^{-6}$) to human health were also identified for the incidental ingestion of shoreline sediment by recreational users due to the concentrations of arsenic under Reasonable Maximum Exposure (RME) conditions; however, this risk was within the acceptable range of 10^{-4} to 10^{-6}. Furthermore, arsenic detected in Site 07 soil samples was within background levels (0.59 to 8.1 mg/kg) and only one ground-water sample from the Phase I, II, and III RI had arsenic detected (63.5 μg/L in MW07-09D) above drinking water MCL (50 μg/L) (note: a duplicate from MW07-09D had a detected arsenic concentration below the MCL). Cancer risks ($> 10^{-6}$) to human health were identified with the ingestion of shellfish [due to concentrations of arsenic, benzo(a)pyrene, benzofluoranthene, dibenzo(a,h)anthracene, and PCB]. Except for arsenic, these chemicals in shellfish were not identified at Site 07 and, therefore, appear to be from an offsite source. Moreover, arsenic was not detected in ground-water samples collected from the southern or western shorelines of Site 07; therefore, the arsenic detected in shellfish may also be from an offsite source. No unacceptable risk has been identified from the Site 07 COC plume or soil to the shellfish in the discharge zones.

Non-cancer risks [Hazard Quotient (HQ) > 1] to human health were associated with the hypothetical exposures resulting from the consumption of deep and bedrock ground water by residential populations (due to concentrations of arsenic, manganese, aluminum, thallium, chromium, chloroform, 1,1-DCE, 1,2-DCE, 1,1,2-TCA, PCE, and TCE) as well as dermal contact with and inhalation of VOC from deep and bedrock ground water while showering by recreational populations (due to concentrations of TCE, chloroform, 1,2-DCE, 1,1-DCE, PCE, and 1,1,2-TCA). Non-cancer risks (HQ > 1) to human health were also associated with concentrations of mercury, zinc, arsenic, copper, cadmium, and PCB in shellfish. However, the elevated cancer and non-cancer risks to human health from eating shellfish are not directly related to Site 07 nor specifically to VOC (the constituents at the site).

The use of deep and bedrock ground water for drinking and showering are possible scenarios requested by EPA, but are not required for the planned use of the site as a conservation area. It is unlikely that ground water at Site 07 would be used as a drinking water source (or for showering) because (1) the aquifer at Site 07 has limited value as a potential drinking water source due to the high salinity identified beneath much of the site, (2) public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) the impacted portion of the aquifer at Calf Pasture Point was found to be low-yielding during the Navy's ground-water investigations. Additionally, the unacceptable exposure scenarios related to ground water were developed using data from the VOC plume area and not the entire site, thereby making them highly conservative (i.e., worst case).

RESULTS OF ECOLOGICAL RISK ASSESSMENT

No significant ecological risks were identified for Site 07. The results of the Facility-Wide Freshwater/Terrestrial ERA (EA 1996b) indicated that there is no significant terrestrial ecological risk from Site 07 surface soil. The results of the Allen Harbor Landfill and Calf Pasture Point Marine ERA (EA 1996a) indicate that, regarding potential risk to the marine ecology, a cause-and-effect relationship could not be established for Site 07.

PRELIMINARY REMEDIATION GOALS (PRG)

PRG for environmental media at Site 07 were developed as performance standards based upon an evaluation of federal and state Applicable or Relevant and Appropriate Requirements (ARARs), as well as NCBC Davisville background concentrations. RIDEM's remediation criteria are contained in the Rhode Island Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases. Based upon these regulations, RIDEM's Method 1 remediation criteria were used for a direct comparison of soil and ground-water data. Background concentrations and the results of the HHRA were also used to evaluate potential COC concentrations at the site. Various chlorinated VOC exceeded PRG in shallow, deep, and bedrock ground water. Surface and subsurface soil data did not exceed PRG.

No chemical-specific Applicable or Relevant and Appropriate Requirements (ARARs) were identified for Site 07. Elevated levels of COC at Site 07 will be addressed through risk-management measures. Therefore, federal and state COC criteria will be used to develop performance standards for evaluating the effectiveness of the remedial alternatives as well as the protectiveness of human health and the environment.

REMEDIAL ACTION OBJECTIVES

Remedial Action Objectives were developed for the environmental media at Site 07 based upon the results of the RI, the HHRA, the ERA, and the Site 07 PRG. No Remedial Action Objectives were identified for surface soil or subsurface soil because no unacceptable terrestrial ecological or human health risks were identified onsite and PRG or background levels were not exceeded. No Remedial Action Objectives were identified for offshore environmental media (e.g., shoreline sediment) or potential offshore ecological receptors (e.g., shoreline shellfish) because (1) although there is a ground-water pathway for Site 07 COC to reach offshore areas, no unacceptable human health risks have been identified from ground-water migration (2) the Marine ERA indicated that a cause-and-effect relationship could not be established for potential risks to the marine ecology from Site 07, and (3) the low ecological risks identified along the shoreline have not been linked to Site 07 (i.e., these low risks are attributable to COC which were not related to Site 07).

Remedial Action Objectives for ground water were developed to address the unacceptable risks identified during the HHRA and the site COC that exceeded the PRG. The following hypothetical pathways were identified in the HHRA:

Cancer pathways
- ingestion of deep and bedrock ground water by residential populations;
- inhalation of VOC from, and dermal contact with, deep and bedrock ground water while showering by recreational users;

Non-cancer pathways
- ingestion of deep and bedrock ground water by residential populations;
- inhalation of VOC from, and dermal contact with, deep and bedrock ground water while showering by recreational users.

The Remedial Action Objectives for ground water were then used to develop General Response Actions which will protect human health and the environment.

GENERAL RESPONSE ACTIONS

Potential risks to human health under the hypothetical exposure scenarios relate to the ingestion or use (showering) of deep and bedrock ground water. In addition, some PRG were exceeded in ground water. Therefore, the identified Remedial Action Objectives were to prevent human exposure to impacted deep and bedrock ground water, and to ensure that the discharge of COC in site ground water continues to pose no unacceptable risks to human health and the environment. General Response Actions and associated remedial technologies were developed to achieve these Remedial Action Objectives. The General Response Actions served as a guide for the development of the remedial alternatives for Site 07.

IDENTIFICATION AND SCREENING OF REMEDIAL ALTERNATIVES

Based upon the Remedial Action Objectives and General Response Actions, the following potential remedial alternatives were developed for Site 07:

Alternative 1: No Action
Alternative 2: Deed Restriction and Long-Term Monitoring
Alternative 3: *In-Situ* Anaerobic Biodegradation
Alternative 4: Vacuum-Vaporizer Wells
Alternative 5: *In-Situ* Permeable Reaction Wall
Alternative 6: Ground-Water Extraction with *Ex-Situ* Air Stripping

To meet the Remedial Action Objectives, each of the remedial alternatives (with the exception of No Action) include a deed restriction prohibiting the future use of site ground water. Prior to the Detailed Analysis, Alternatives 1 through 6 were first screened with respect to effectiveness, implementability, and cost in accordance with the National Contingency Plan (NCP). The screening results were as follows:

Alternative 1: No Action

The "No Action" alternative serves as a baseline comparison against which the other remedial alternatives are compared. Under this alternative, no remedial actions or institutional controls would be implemented. As required by CERCLA Section 121(c), 5-year reviews would be conducted because COC would be left onsite above the established health-based levels.

Screening Results

Because no remedial components are specified, the No Action alternative would not be effective or implementable for meeting Remedial Action Objectives. However, the NCP requires that the No Action alternative to be retained as a baseline comparison for the other remedial alternatives; therefore, Alternative 1 was retained for the Detailed Analysis.

Alternative 2: Deed Restriction and Long-Term Monitoring

Alternative 2 would protect human health and the environment through the following remedial components:

- Deed restriction prohibiting the future use of site ground water;
- Long-term monitoring to ensure that the plume continues to pose no unacceptable risks; and

  5-year reviews.

Under Alternative 2, site risks will be addressed through a deed restriction prohibiting the future use of site ground water. A long-term monitoring program will be conducted to ensure that the plume continues to pose no unacceptable risks in the future. As required by CERCLA Section 121(c), 5-year reviews will be conducted because COC will be left onsite above the established health-based levels.

Screening Results

Alternative 2 would be effective for addressing the site risks and Remedial Action Objectives based on the limited site risks (which would be addressed through the deed restriction and long-term monitoring program) and the technical limitations for addressing all site media (e.g., COC in fractured bedrock and/or potential residual DNAPL). Alternative 2 is also implementable. Therefore, Alternative 2 was retained for the Detailed Analysis.

Alternative 3: *In-Situ* Anaerobic Biodegradation

Alternative 3 is an innovative technology involving *in-situ* ground-water treatment. This alternative will protect human health and the environment through the following remedial components:

- Deed restriction prohibiting the future use of site ground water;
- Installation of injection wells to be used to inject a substrate which would promote the anaerobic biodegradation of organic COC within portions of the plume;
- Long-term monitoring (to evaluate the effectiveness of assisted biodegradation and to ensure that the plume continues to pose no unacceptable risks); and
- 5-year reviews.

This alternatives provides for treatment of VOC in shallow and deep ground water primarily in the vicinity of the source areas. This alternative may have limited effectiveness for bedrock ground water. Conceptually, five deep injection wells and two shallow injection wells would be installed in the vicinity of the two plumes (i.e., the deep plume below the DANC disposal area and the shallow plume near the southern shoreline). An additional deep well would be installed in the southern portion of the site in an area where high total chlorinated VOC were detected. The shallow wells would be installed into the upper sand unit and the deep wells would be installed in the lower sand/till unit. For 8 hours per day, each of the injection wells would be used to inject approximately 2 to 5 gallons per minute (gpm) of an aqueous substrate (carbon source) into the source areas. Other demonstration sites have indicated that, with the addition of this food source (such as acetate or sodium benzoate), intrinsic microorganisms will increase the consumption of dissolved oxygen and will then, under the generated anaerobic conditions, begin to use the chlorinated organic compounds as an oxygen substitute. A treatability study would be conducted to confirm and optimize the effectiveness of this process at Site 07. Pilot studies may also be required to determine the most effective injection techniques (e.g., single wells, diffusers, a well point system, etc.). Elevated concentrations of COC in areas of the site which are not under the influence of the anaerobic system (e.g., bedrock ground water and downgradient portions of the plume in deep ground water) would not be effectively mitigated with this alternative; however, the risks associated with these COC would be addressed through the deed restriction.

Screening Results

Alternative 3 will be effective for addressing the site risks and Remedial Action Objectives, although a treatability study will be required to ensure the effectiveness of the innovative treatment technology. Therefore, Alternative 3 was retained for the Detailed Analysis.

Alternative 4: Vacuum-Vaporizer Wells

Alternative 4 is an innovative technology which involves *in-situ* ground-water treatment. This alternative will protect human health and the environment through the following remedial components:

- Deed restriction prohibiting the future use of site ground water;
- Installation and operation of Vacuum-Vaporizer Well systems to treat the ground-water source areas;
- Treatment of offgas from Vacuum-Vaporizer Wells;
- Long-term monitoring (to evaluate the effectiveness of the Vacuum-Vaporizer Well system and to ensure that the plume continues to pose no unacceptable risks); and
- 5-year reviews.

This alternative provides for treatment of VOC in the shallow and deep ground-water source areas. Conceptually, three Vacuum-Vaporizer Wells would be installed in the vicinity of the DANC disposal area within the lower sand/till unit. One Vacuum-Vaporizer Well would be installed in the southern portion of the site near MW07-19S. The dual-screen, Vacuum-Vaporizer Wells operate by drawing in ground water from the lower screen of the well along with introduced atmospheric air. Within the stripping zone of the well, VOC from this ground water would partition into the air. The offgas air removed from the wells would be treated with activated carbon prior to discharge to the atmosphere. The treated ground water would re-enter the aquifer through the upper screen of the well. The wells would be installed so that the upper screens are not located within the silt unit (so that discharge of treated ground water would not be restricted). Typically, the radius of influence for this technology is highly dependant on site geology (e.g., horizontal vs. vertical hydraulic conductivities, thickness of the geological units, as well as well specifications such as screen length and spacing);

therefore, a pilot study would be performed to determine and optimize the effectiveness of this technology at Site 07 (other demonstration sites/models have indicated a wide range of treatment radii between 35 and 80 ft per well).

Elevated concentrations of COC in areas of the site which are not under the influence of the Vacuum-Vaporizer Well system (e.g., bedrock ground water and downgradient portions of the plume in deep ground water) would not be effectively mitigated with this alternative; however, the risks associated with these COC would be addressed through the deed restriction.

Screening Results

Alternative 4 will be effective for addressing the site risks and Remedial Action Objectives although a treatability study will be required to ensure the effectiveness of the innovative treatment technology under site-specific conditions. Therefore, Alternative 4 was retained for Detailed Analysis.

Alternative 5: *In-Situ* Permeable Reaction Wall

Alternative 5 is an innovative technology which involves the *in-situ* treatment of shallow and deep ground water exiting Site 07. This alternative will protect human health and the environment through the following remedial components:

- Deed restriction prohibiting the future use of site ground water;
- Installation of an *in-situ* system to channel (via sheet pile walls) affected shallow and deep ground water through a permeable, reactive wall that will promote the degradation of chlorinated COC;
- Long-term monitoring (to evaluate the effectiveness of the *In-Situ* Permeable Reaction Wall system for reducing chlorinated COC concentrations migrating offsite via shallow/deep ground water and to ensure that the plume continues to pose no unacceptable risks); and
- 5-year reviews.

This alternative provides for treatment of VOC in shallow and deep ground water as it exits the site (rather than from within the source area). Conceptually, approximately 1,700 linear ft of sheet pile wall would be installed down to the bedrock surface on the eastern and western sides of the plumes in order to channel the VOC plumes through an *In-Situ*, Permeable Reactive Wall located along the southern shoreline. This treatment zone would be constructed with a sheet pile wall containing intermittent, permeable treatment sections (containing iron-based catalysts) along its length. The permeable treatment sections would be approximately 4 ft wide $\times$ 35 ft deep and have a total length of 200 ft. The iron-based catalyst would promote the degradation of halogenated compounds by abiotic or biological processes as they pass through the wall (i.e., the system induces conditions where halogen atoms are replaced by hydrogen atoms). A treatability study would be performed to develop the proper catalyst/soil mixture. Treated ground water would exit the downgradient side of the permeable reaction wall. The treatment sections of the reaction wall would be replaced/maintained, as required, in order to replenish the iron-based catalyst. Ground-water monitoring wells will also be installed on the downgradient side of the reaction wall to monitor system performance. Four deep and three shallow monitoring wells will be installed for this purpose. Piezometers would be used to evaluate the effectiveness of the sheet pile walls for controlling shallow and deep ground-water flow.

Most VOC (i.e, volatile COC except for benzene and 1,2-DCA) in shallow and deep ground water would be degraded as they exit Site 07. This alternative would not treat ground-water source areas or bedrock ground-water; however, the risks associated with COC in these areas would be addressed through the deed restriction.

Screening Results

Alternative 5 will be effective for addressing the site risks and Remedial Action Objectives although a treatability study will be required to ensure the effectiveness of the innovative treatment technology under site-specific conditions. Therefore, Alternative 5 was retained for Detailed Analysis.

Alternative 6: Ground-Water Extraction with *Ex-Situ* Air Stripping

Alternative 6 is a "pump-and-treat" option which will protect human health and the environment through the following remedial components:

- Deed restriction prohibiting the future use of site ground water;
- Installation of ground-water extraction systems within the source areas of the two ground-water plumes;
- Installation of manifold piping to carry extracted ground water into a central, onsite, treatment system;
- Treatment of ground water with a series of onsite unit processes consisting of pre-treatment to remove particulates and dissolved metals (conventional filtration, coagulation, flocculation, sedimentation) and air stripping to remove VOC (with offgas treatment);
- Discharge of treated ground water to Narragansett Bay;
- Long-term monitoring (to evaluate the effectiveness of the pump-and-treat system and to ensure that the plume continues to pose no unacceptable risks); and

- 5-year reviews.

This alternative provides for the *ex-situ* treatment of ground water from the source areas. Conceptually, three extraction wells would be installed into the deep aquifer in the vicinity (slightly downgradient) of the DANC disposal area and two extraction wells would be installed into the shallow aquifer within the second plume at MW07-19S and MW07-21S. The deep wells would be screened within the lower sand/till unit and the shallow wells would be screened within the upper sand unit. The deep and shallow wells would be operated at a pumping rate of 5 and 10 gpm, respectively. Ground water would be extracted at a low flow-rate because (1) the hydraulic conductivity of the deep aquifer is low, (2) a low flow-rate would reduce salt water migration toward the deep VOC plume (the salt content of the extracted ground water may complicate the operation of the *ex-situ* ground-water treatment processes), and (3) high rate pumping near MW07-21S would likely bring in harbor water which would create additional costs through the unnecessary treatment and/or conveyance of additional volumes of clean salt water.

A manifolded piping system would be constructed to transport the extracted ground water to a central, onsite treatment system. The ground-water treatment system would consist of a multi-stage process including pre-treatment, air stripping, and effluent treatment/disposal. Pre-treatment (filtration, coagulation, flocculation, sedimentation) may be required to remove particulates and dissolved metals which may reduce the effectiveness of air stripping. Air stripping would be used to transfer VOC from ground water to air through a counter-current flow packed tower. Treated ground water would be collected from the bottom of the tower, passed through a final-stage (polishing) Granular Activated Carbon (GAC) canister, as necessary, and discharged to Narragansett Bay. Periodic monitoring of the effluent will be required to ensure that the discharge meets the substantive federal and state discharge requirements. The offgas air from the air stripping tower would be treated with GAC prior to discharge to the atmosphere, as necessary.

Screening Results

Alternative 6 will be effective for addressing the site risks and Remedial Action Objectives. However, this pump-and-treat alternative will have limited/diminishing treatment capabilities relative to its high costs for the long-term management of limited site risks. Therefore, Alternative 6 was not retained for the Detailed Analysis.

COMPARISON OF REMEDIAL ALTERNATIVES

The five remedial alternatives retained after the screening were each addressed in greater detail based on the criteria outlined in the NCP. The comparison of remedial alternatives was intended to identify the advantages and disadvantages of each alternative relative to one another based on the NCP criteria so that the key decision-making trade-offs can be identified. Comparisons are made for the following alternatives which have been retained from the above screening:

- Alternative 1 - No Action
- Alternative 2 - Deed Restriction and Long-Term Monitoring
- Alternative 3 - *In-Situ* Anaerobic Bioremediation
- Alternative 4 - Vacuum-Vaporizer Wells
- Alternative 5 - *In-Situ* Permeable Reaction Wall

OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The unacceptable risks to human health at the site are associated with the consumption and use (showering) of deep and bedrock ground water. Alternatives 2 through 5 will be equally protective of human health through implementation of a deed restriction prohibiting the future use of site ground water. The No Action alternative would not protect human health because the risks would not be addressed. No unacceptable ecological risks were identified at, or associated with, Site 07.

COMPLIANCE WITH ARARS

No chemical-specific ARARs were identified for Site 07. Elevated levels of COC at Site 07 will be addressed through risk-management measures. Therefore, federal and state COC criteria will be used to develop performance standards for evaluating the effectiveness of the remedial alternatives as well as the protectiveness of human health and the environment.

Alternative 1 (No Action) will not comply with ARARs because it would not address the unacceptable risks identified at the site. Alternatives 2 through 5 would address the site risks through a deed restriction prohibiting the future use of site ground water as well as through long-term monitoring. Various chlorinated-VOC in ground water have been detected above RIDEM's Method 1 "Class GB" criteria which are performance standards for Site 07. Alternatives 3 and 4 provide for some treatment of shallow and deep ground water. Alternative 3 may be more effective than Alternative 4 because a greater portion of the plume would be under the influence of the remediation system. Alternative 5 would not reduce COC concentrations at the source areas but provides for downgradient treatment of shallow and deep ground water exiting the site. Alternatives 3 and 4 would provide little treatment of bedrock ground water. Alternative 5 would not treat bedrock ground water.

The location-specific ARARs include requirements for the protection of marshes, wetlands, and endangered species. Alternative 1 and 2 would have the least impact on the isolated marshes/wetlands or potential endangered species/species habitat at the site because no construction operations would be undertaken. However, Alternative 1 would not satisfy location-specific ARARs because it does not include a monitoring program which would ensure that wetlands are not being impacted by ground-water migration. The monitoring programs under Alternatives 2 through 5 will be protective of wetlands. Alternatives 3 and 4 may have some impact on the isolated marshes/wetlands or potential endangered species/species habitat resulting from the construction activities (e.g., drill rigs) associated with well installation and building an onsite injection system (Alternative 3) or offgas treatment system (Alternative 4).

Alternative 5 would have the greatest potential for disturbing the isolated marshes/wetlands or potential endangered species/species habitat at the site resulting from the installation of a sheet pile wall and permeable reaction wall surrounding the eastern, western, and southern sides of the plume. The majority of the marshes at Site 07 are located along the shoreline and the eastern portion of the site (where the walls would be installed). Other potential disturbances from Alternative 5 include changing the extent of salt water intrusion (thereby, in some localized areas, potentially impacting the established vegetation associated with salt water or brackish marsh areas).

Alternatives 2 through 5 would be conducted in accordance with action-specific ARARs. Action-specific ARARs were not identified for Alternative 1 because no remediation technologies or monitoring are specified.

LONG-TERM EFFECTIVENESS AND PERMANENCE

The No Action alternative will not be effective in the long-term because the unacceptable risks to human health would not be controlled or mitigated. Alternatives 2 through 5 will be equally effective and permanent in the long-term for addressing site risks with the implementation of a long-term monitoring program and a deed restriction prohibiting the future use of site ground water. Periodic inspections of the land use will be conducted to ensure that the deed restriction remains effective in the long-term.

Alternatives 3 through 5 will be more effective than Alternatives 1 and 2 for addressing PRG in shallow and deep ground water because these alternatives include ground-water treatment components. Ground-water treatment under Alternatives 3 would result in the degradation of COC in onsite shallow and deep ground water. The ground-water treatment component of Alternative 4 would transfer COC from shallow and deep ground-water source areas to another media (i.e., GAC) which would require subsequent treatment and/or disposal. Alternative 5 would degrade COC in shallow and deep ground water exiting Site 07. Alternatives 3 and 4 would have little effectiveness for treating bedrock ground water. Alternative 5 would not treat bedrock ground water.

REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

Alternatives 1 and 2 do not specify ground-water treatment which will reduce the toxicity, mobility, or volume of COC in ground water.

Alternatives 3, 4, and 5 would afford the most reduction of toxicity, mobility, and/or volume because these options use treatment technologies to mitigate COC concentrations in affected portions of the plume in shallow and deep ground-water. Treatment of affected ground water located in the fractured bedrock at Site 07 may be technically impracticable. Alternative 3 may provide the most reduction of COC in shallow and deep ground water because it treats the largest source area. Alternative 4 will treat COC in the shallow and deep source areas.

Alternative 5 will not treat COC in the source areas but will be the most effective for reducing the toxicity, mobility, and volume for COC in shallow and deep ground water exiting the site.

Alternative 3 end-products which result from complete anaerobic biodegradation are innocuous. Incomplete biodegradation (or active bioremediation under Alternative 3) can also result in the formation of VC (a more toxic compound than the parent compound, 1,2-DCE). Alternative 5 will reduce the toxicity and volume of COC in shallow and deep ground water exiting the site through treatment and will reduce the mobility of COC in shallow and deep ground water through installation of steel sheet pile walls. Alternative 4 would reduce the mobility and volume of COC in shallow and deep ground water by removing VOC from ground water and treating with carbon adsorption.

SHORT-TERM EFFECTIVENESS

The deed restriction specified under Alternatives 2 through 5 will be equally effective in the short-term for addressing ground-water risks at Site 07. The No Action alternative will not be effective for addressing risks at the site because no remedial actions or institutional controls would be implemented to prevent potential human exposure to deep/bedrock ground water.

Alternatives 1 and 2 will not produce any new risks to the community or to site workers because no treatments of affected ground water is specified. During the construction activities for Alternatives 3, 4, and 5, potential hazards to site workers (e.g., construction workers, treatment system operators, sampling personnel) include potential dermal contact with and inhalation of VOC volatilizing from soil and ground water. Of these, Alternative 3 would present the least risk to site workers because potential contact with COC would only occur during well installation and ground-water sampling. Alternative 4 would present some risk to site workers because, in addition to well installation and ground-water sampling, COC could potentially be discharged to the atmosphere during operation of the Vacuum-Vaporizer Well system (however, GAC treatment will be used if these discharge levels are found to be unacceptable). Alternative 5 would present the most risk to site workers because, in addition to ground-water sampling, potential direct contact with affected media would result from trenching operations during construction of the *in-situ* reaction wall. Inhalation hazards associated with fugitive dust and/or volatilizing VOC may also be a concern during excavation of the trench. Alternatives 3, 4 and 5 using appropriate engineering controls (e.g., dust suppression with water) and safety equipment (e.g., use of personal protective equipment, and field monitoring instruments) should afford adequate protection to site workers and the surrounding community.

Installation of sheet pile walls under Alternative 5 will likely generate high noise levels [e.g., greater than 85 decibels (dB) at the source]. This would only be a short-term nuisance to the local community and would not likely generate noise levels of concern to the public because of the distance between the site and populated areas.

IMPLEMENTABILITY

The No Action alternative will not be implemented because it does not address the risks at Site 07.

The Deed Restriction and Long-Term Monitoring alternative will be implementable because all unacceptable risks will be addressed and ground-water treatment may not be warranted (e.g., ground water is not and is not likely to be a source for potable water, no evidence of offshore risks due to ground water have been identified at Site 07, treatment of COC in bedrock ground water may be technically impracticable). The deed restriction specified under Alternatives 3, 4, and 5 would be equally implementable as Alternative 2.

The technical implementability of Alternatives 3, 4, and 5 will be dependant upon the results of the respective treatability studies for these innovative technologies. The trenching required under Alternative 5 for the construction of the *In-Situ* Permeable Reaction Wall could be complicated by the proximity of Allen Harbor (which results in a shallow water table). Likely difficulties associated with implementing Alternative 3 include developing a well location and flow rate design which will adequately compensate for potential mass transfer limitations in a heterogeneous soil matrix and silt layer. Difficulties associated with implementing Alternative 4 include developing a well location and flow rate design which will adequately compensate for potential preferential flow paths through the heterogeneous soil matrix and silt layer. Preferential flow paths or channels throughout the radius of influence of the Vacuum-Vaporizer-Wells under Alternative 4 also may result in untreated portions of the subsurface aquifer. Difficulties associated with implementing Alternative 5 include determining the proper retention time and iron content of the reaction wall as well as compensating for potential adverse effects from bicarbonate levels in the ground water which could cause precipitates to form within the reaction wall.

The monitoring programs under Alternatives 2 through 5 will be readily implementable because the existing monitoring well network can be used or modified.

COST

The cost comparison is based on a preliminary review of each alternative and approximate design parameters and vendor quotes. The cost estimates are anticipated to be within -30% to +50% of the actual costs for completing the remedial actions. Thus, these costs are primarily used as an order of magnitude comparison.

These are no capital costs for Alternative 1 (No Action). Costs for the 5-year reviews of the No Action decision would be nominal.

Costs for Alternative 2 (Deed Restriction and Long-Term Monitoring) consist of an estimated capital cost of $130,000. Annual O&M costs ($247,000) are for the long-term monitoring program. The total 30-year net present worth cost of Alternative 2 is $1,679,000.

Costs for Alternative 3 (*In-Situ* Anaerobic Bioremediation) include an estimated $1,000,000 in capital costs which include a treatability study and installation of an injection well system. Annual O&M costs ($468,000) consist of system operation and long-term monitoring. The total 30-year net present worth cost of Alternative 3 is estimated to be $3,619,000.

Costs for Alternative 4 (Vacuum-Vaporizer Wells) include an estimated $1,383,000 in capital costs. Capital costs include a pilot study and installation of a series of Vacuum-Vaporizer Wells manifolded into an offgas treatment system. Annual O&M costs ($468,000) consist of system operation and long-term monitoring. The total 30-year net present worth cost of Alternative 4 is estimated to be $5,867,000.

Costs for Alternative 5 (*In-Situ* Permeable Reaction Wall) include an estimated $6,285,000 in capital costs. Capital costs include a treatability study and installation of the treatment system comprised of steel sheet pile walls and an *In-Situ* Permeable Reaction Wall. Annual O&M costs ($357,000) consist of periodic reaction wall maintenance/replacement and long-term monitoring. The total 30-year net present worth cost of Alternative 5 is estimated to be $9,062,000.

1. INTRODUCTION

1.1 PURPOSE AND ORGANIZATION OF REPORT

1.1.1 Purpose

This Feasibility Study (FS) report develops and evaluates remedial alternatives for Installation Restoration (IR) Program Site 07 (Calf Pasture Point) at the Naval Construction Battalion Center (NCBC) Davisville, Rhode Island. This FS was performed by EA Engineering, Science, and Technology (EA) and evaluates a whole-site remedy. As such, this FS builds upon findings of the Phase I, II, and III Remedial Investigations (RI), Human Health Risk Assessment (HHRA), and Marine and Freshwater/Terrestrial Ecological Risk Assessments (ERA) performed for Site 07 and Allen Harbor. This report has been prepared in accordance with the Scope of Work for Contract Task Order (CTO) 0032, Contract N62472-92-D-1296. The Record of Decision (ROD) for Site 07 will include the "Calf Pasture Point Munitions Bunkers" Study Area; the results of this investigation are being presented under a separate Study Area Screening Evaluation report (Halliburton NUS 1994) and Close-Out Report (Foster Wheeler 1997).

This FS has been conducted under the Navy's IR Program in accordance with the requirements under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP, 40 CFR Part 300) establishes the framework for performing the FS. The U.S. Environmental Protection Agency (EPA) document "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA - Interim Final" (EPA 1988) was used as the guidance document for preparation of this report. NCBC Davisville is currently listed as a Superfund site on the National Priorities List (NPL).

The objectives of this FS report are to summarize the previous investigations performed at the site and, based on these investigations, to develop, screen, and evaluate alternative remedial actions for Site 07. Remedial alternatives described in this report are developed and screened based on federal and state Applicable or Relevant and Appropriate Requirements (ARARs), To Be Considered (TBC) regulatory guidelines, and the findings of the RI.

1.1.2 Organization

The FS report is divided into five Chapters:

- Chapter 1 - Introduction: The chapter identifies the purpose of this FS and summarizes background information, including the findings of the previous investigations at Site 07.

- Chapter 2 - Identification and Screening of Technologies: This chapter provides an overview of the CERCLA FS evaluation process, identifies ARARs and TBC guidelines, identifies media/receptors of concern, and establishes Remedial Action Objectives and General Response Actions. This chapter also includes the initial identification and screening of potential remedial technologies.

- Chapter 3 - Development and Screening of Alternatives: In this chapter, remedial alternatives are developed using technologies which are retained from the technology screening. The alternatives are examined with respect to effectiveness, implementability, and cost.

- Chapter 4 - Detailed Analysis of Alternatives: In this chapter, the remedial alternatives which were retained for detailed analysis are examined with respect to seven of the nine evaluation criteria identified in the Revised NCP. The nine criteria are: overall protection of human health and the environment; compliance with ARARs; long-term effectiveness and permanence; reduction of toxicity, mobility, and volume through treatment; short-term effectiveness; implementability; cost; state acceptance; and community acceptance. The criteria of state acceptance and community acceptance will be addressed during the ROD.

- Chapter 5 - Summary and Comparison of Remedial Alternatives: This chapter summarizes and compares the results of the Detailed Analysis of Alternatives conducted in Chapter 4.

1.2 BACKGROUND INFORMATION

1.2.1 NCBC Davisville

NCBC Davisville is located in the Town of North Kingstown, Rhode Island, approximately 18 miles south of the state capital, Providence (Figure 1-1). NCBC Davisville was composed of three areas: the Main Center (Zones 1 through 4), the West Davisville storage area, and Camp Fogarty—a training facility located approximately 4 miles west of the Main Center (Figure 1-2). Camp Fogarty was transferred to the U.S. Department of the Army in December 1993 and is assigned to the Rhode Island National Guard. Adjoining the southern boundary of the Main Center is the decommissioned Naval Air Station (NAS) Quonset Point, which was transferred by the Navy to the Rhode Island Port Authority (RIPA) [currently named the Rhode Island Economic Development Corporation (RIEDC)] and others between 1975 and 1980.

NCBC Davisville was primarily used for training Naval seamen in construction operations, and as storage and freight yards for construction materials. As a result, NCBC Davisville is comprised primarily of warehouse space and freight yards, most of which are currently empty. NCBC Davisville closed on 1 April 1994. Most of the staff and materials have been moved offsite. Currently, facilities management and security staff engaged with base closure remain on-base.

The Davisville/Quonset Point area was originally settled by Europeans in the late 17th century. Quonset Point was the location of the first annual encampment of the Brigade Rhode Island Militia in 1893. During World War I, it was a campground for the mobilization and training of troops, and was later the home of the Rhode Island National Guard. In the 1920s and 1930s, it was used as a summer resort for local residents and for agriculture.

In 1939, Quonset Point was acquired by the Navy and construction of the air station and pier began in 1940. During construction, millions of cubic yards of sediment were dredged to create the ship basin and channel. The dredged material was used to create a 1.5 square mile section in Quonset's northeast corner, as well as what is now Calf Pasture Point. A 1939 aerial photograph shows Allen Harbor in its natural configuration. The harbor was formed by two spits one trending north south and one trending northeast. In the center of the harbor was a large island which occasionally was connected to the northeast trending spit. A 1958 aerial photograph of Calf Pasture Point shows the entire surface stripped of vegetation (except for sparse vegetation on the bedrock outcrop) and covered with tire tracks. Wartime activities at NAS Quonset Point included training aircraft carrier pilots and crews, overhauling aircraft, supplying military equipment and planes, and providing coastal defense.

By 1942, the operations at NAS Quonset Point had outgrown the station. Adjacent land at Davisville was designated as the Advanced Base Depot and a pier was constructed. Later that year, the Naval Construction Training Center (NCTC), known as Camp Endicott, was established at Davisville to train newly established construction battalions. By November 1942, the camp was at capacity, housing 15,000 enlisted personnel and 350 officers. More than 100,000 personnel were trained at Camp Endicott by the end of World War II.

After the war, NAS Quonset Point continued as an operating base for aircraft and ships and was the homeport of carrier-based squadrons. The NCBC Davisville area experienced reduced activity between World War II and the Korean Conflict. In 1951, it became the Headquarters of the Construction Battalion Center. The Construction Battalion Center loaded ships and trained personnel for both the Korean and Vietnam conflicts. In 1952, the Naval Construction Training Unit was established at Davisville.

The Antarctic Development Squadron Six was moved to NAS Quonset Point in 1956. A Naval Air Rework Facility (NARF) was created there in 1967. The NARF performed overhaul and repair work previously handled by NAS Quonset Point.

In 1974, the NAS and the NARF at Quonset Point were decommissioned, and operations at the base were greatly reduced pursuant to the Shore Establishment Realignment Act of 1973. NCBC Davisville's mission was to provide mobilization support to the active Naval Construction Force; to act as a mobilization base for the rapid assembly outfitting and readying of Reserve Construction Battalions; to store, preserve, and ship advanced base and mobilization stocks; and to procure, receive, pack, and ship collateral equipment for Atlantic, European, and Caribbean military construction projects. NAS Quonset Point was transferred from the Navy to RIPA and others from 1974 to 1980. In 1991, the closure of NCBC Davisville was announced, and operations were phased down to minimum staffing levels for public works, maintenance, security, and personnel.

NCBC Davisville was decommissioned on 25 March 1994 and closed on 1 April 1994. The facility has been transferred to Northern Division, Naval Facilities Engineering Command, which has caretaker status pending disposal.

1.2.2 Site 07 - Calf Pasture Point

This FS addresses the IR Program site (Site 07) located on Calf Pasture Point, a peninsula in the northeastern portion of NCBC Davisville (Figure 1-2). Prior to 1940, the central portion of the Calf Pasture Point peninsula was a portion of Allen Harbor (Figure 1-3). During the 1942/1943 dredging activity by the Navy for the pier area along the Narragansett Bay Shoreline south of Site 07, dredge material was placed at Calf Pasture Point, thereby filling in the shallow lagoon. Allen Harbor was also dredged and the material was likely placed in Calf Pasture Point lagoons as well as joining the island to the south to form what is now known as Spink Neck.

Calf Pasture Point is bounded to the southwest and south by Allen Harbor and its entrance channel, respectively; to the east by Narragansett Bay, and to the west and north by Sanford Road. Vehicular access to Calf Pasture Point is controlled by a fence with locked gate at the Sanford Road entrance. Calf Pasture Point contains three former munitions bunkers (Buildings 59, 60, and 339) located along Magazine Road. The bunkers are earthen covered and are located in the middle of Calf Pasture Point (Figure 1-4) just north, east, and south of the bedrock outcrop [a prominent hill with a maximum elevation of approximately 55 ft above mean sea level (MSL)—the highest location at Calf Pasture Point]. The Navy demolished Bunker 339 in February 1997. By March 1997, the Navy had cleaned Bunkers 59 and 60 and welded the doors shut. The Navy prepared a Close-Out report in October 1997.

Site 07 comprises the area of Calf Pasture Point south of the bunkers, i.e., south from monitoring well MW07-07S and generally east of the dirt access road that extends south to the entrance channel shoreline (Figure 1-4). Calf Pasture Point is currently overgrown with shrubs, small trees, grasses, and reeds.

Calf Pasture Point was reportedly the site of three distinct disposal incidents. These incidents reportedly involved disposal of twenty 5-gallon cans of calcium hypochlorite, thirty to forty 35-gallon containers of an unidentified chloride compound, and an estimated 2,500 3-gallon cans containing "Decontaminating Agent Non-Corrosive" (DANC) solution. DANC is a reactive, chlorinated compound. The following is a summary of the historic disposal events as described in the Initial Assessment Study of NCBC Davisville (Fred C. Hart 1984a):

- Between 1960 and 1974, approximately twenty 5-gallon cans (100 gallons) of calcium hypochlorite (bleach) were disposed in a drainage ditch alongside Bunker 60 at Calf Pasture Point. Between 1978 and 1982, metal cans containing calcium hypochlorite were removed from this site for offsite disposal. This is the only documented remedial activity known to have occurred at the site. Calcium hypochlorite [$Ca(OCl)_2$] is a water-soluble solid which degrades rapidly in water. The commercial product usually contains 50% or more of $Ca(OCl)_2$. It could not be determined if all of the calcium hypochlorite disposed in this area was removed, and the ultimate location of offsite disposal was not identified.

- In 1973, thirty to forty 35-gallon cardboard containers of an unidentified chloride compound were stored at Calf Pasture Point. This material reportedly originated from the utilities school, where it was used for water treatment purposes. These containers became deteriorated over time and were reportedly buried at the site. Although the chloride compound was not identified, it may have been ferric chloride, a black-brown, corrosive solid which is readily soluble in water. It is expected that most chlorides would leach from the cardboard containers during the period of their burial at the site.

- At some time between 1968 and 1974, a trench measuring approximately 10 ft $\times$ 20 ft $\times$ 15 ft was filled with 3-gallon cans containing DANC solution. Accordingly, this was estimated to be approximately 2,500 cans (Fred C. Hart 1984a). The cans were reportedly buried at an undetermined location at Calf Pasture Point. However, through the various phases of investigation at Site 07, the approximate location of the disposal area has been inferred (Figure 1-4). The DANC solution consisted of two separate chemicals that were mixed to form a decontaminating solution: 1,3-dichloro-5,5-dimethyl-hydantoin (a crystal); and acetylene tetrachloride [a.k.a., 1,1,2,2-perchloroethane (1,1,2,2-PCA): a heavy, colorless liquid]. 1,3-dichloro-5,5-dimethyl-hydantoin and hydantoin products are oxidizing agents and readily break down to release chlorine when contacted by water. The DANC was apparently used during Defense Disaster Preparedness Training activities during which biological and nuclear warfare attacks were simulated.

As described in Section 1.2.3.1, several 3-gallon rusty cans, some containing a solid white substance comprised mostly of calcium, were unearthed during the Confirmation Study at Calf Pasture Point. No further waste materials from past disposals have been found at Site 07.

1.2.3 Previous Investigations and Studies at Site 07

Several previous investigations have been performed at NCBC Davisville in conjunction with Navy, the Rhode Island Department of Environmental Management (RIDEM), and the EPA. The primary Navy investigation reports that pertain to characterization of Site 07, in chronological order, include the following:

- Initial Assessment Study (IAS) (Fred C. Hart 1984a)
- Confirmation Study (CS) - Verification Step Report (TRC 1987)
- CS - Characterization Step Report (TRC 1988)
- Phase I RI Report (TRC 1991)
- Phase II RI Report (TRC 1994)
- Draft Final Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment Report (EA 1996a)
- Draft Final Allen Harbor Landfill and Calf Pasture Point Marine Ecological Risk Assessment Report (SAIC 1996b)
- Phase III RI Report (EA 1998a)
- Human Health Risk Assessment (EA 1998a)

More detailed descriptions of previous investigations at Site 07 are provided in the Phase III RI report.

1.2.3.1 Previous Investigations—U.S. Navy

Initial Assessment Study (Fred C. Hart 1984a)

In 1983, the Navy Assessment and Control of Installation Pollutants (NACIP) Office initiated an IAS of potentially contaminated sites at NCBC Davisville. The IAS identified a total of fourteen potentially contaminated sites. The EPA identified ten additional sites (Sites 15 through 24), for a total of twenty-four potentially contaminated sites. The IAS concluded that three of the fourteen sites identified at NCBC Davisville posed a sufficient threat to human health or the environment to warrant additional investigation. The IAS report recommended that the Navy conduct a Confirmation Study (CS), as defined under the NACIP Program, on the following three sites: Site 05 - Transformer Oil Disposal Area; Site 07 - Calf Pasture Point; and Site 09 - Allen Harbor Landfill. Based on the potential for the discharge and migration of PCA into Allen Harbor and Narragansett Bay, and the potential impact on the marine life and wetlands, the IAS recommended the Calf Pasture Point site for a CS.

A copy of the IAS was sent by the Navy to RIDEM for review and comment. In a letter dated 9 October 1984, RIDEM presented its review findings and requested that the Navy add seven of the fourteen sites originally identified in the IAS to the list of sites to be examined further in the upcoming CS. The Navy agreed to RIDEM's request and added the seven sites.

Confirmation Study - Verification Step (TRC 1987)

Beginning in 1985, thirteen sites (including Site 07) were investigated as part of the Verification Step of the CS. The scope of work for the Verification Step included investigation of the three sites identified in the IAS as needing additional study, the seven sites requested by RIDEM, and three sites identified by the Navy that warranted further investigation. Based upon the results of the Verification Step of the CS, additional sampling and investigations were recommended.

Confirmation Study - Characterization Step

In March 1988, the Navy implemented the recommendations of the CS - Verification Step by developing a plan of action to conduct more extensive sampling under a NACIP CS - Characterization Step. The CS - Characterization Step performed at Site 07 included a magnetometer survey and the installation of two monitoring wells (MW07-01S and MW07-02S). The purpose of the magnetometer survey was to locate buried drums on the site. Of the eight magnetic anomalies identified, four could be attributed to possible buried drums. Upon augering and shoveling in the area of the strongest anomaly, several 3-gallon rusty cans, some containing a solid white substance comprised mostly of calcium, were unearthed. The monitoring wells were placed downgradient of the buried containers and sampled eight days after installation. In ground water, 1,1,2,2-PCA was not detected but an unidentified Volatile Organic Compound (VOC) was detected at concentrations below 0.2 mg/L. The CS recommended the removal of contaminated soil and containers, backfilling and revegetation of the area, or a No Action alternative that involved only ground-water quality monitoring (TRC 1988).

1.2.3.2 Previous Investigations—EPA

EPA proposed NCBC Davisville for inclusion on the NPL in July 1989. NCBC Davisville was added to the NPL on 21 November 1989. A Hazard Ranking System (HRS) scoring was undertaken by EPA to support the proposed final listings. The HRS was based on existing information; a Preliminary Assessment/Site Inspection (PA/SI) was not performed. The HRS package was based on the 24 potential sites; the areas designated 1 through 14 coincide with the fourteen areas identified in the Navy's IAS. The remaining potential areas (15 through 24) were identified by the EPA from an "Off-Site Activity Investigation" report (Fred C. Hart 1984b). The HRS noted that areas 15 through 24 are on property not currently owned or operated by the U.S. Navy. Several of these areas are being investigated by the U.S. Army Corps of Engineer's Formally Used Defense Site (FUDS) program. The HRS used an aggregate of the two most seriously impacted sites to form the basis of the ranking. The two sites used in the HRS evaluation were Site 09 (Allen Harbor Landfill) and Site 07 (Calf Pasture Point).

1.2.3.3 Remedial Investigations

In March 1988, the Navy's three-phase NACIP Program was restructured to conform with EPA's four-phase program. This change was predicated by SARA of 1986. Thus, the Navy changed its NACIP Program to closely parallel the EPA requirements for remedial actions at Superfund sites. The Navy's program is now referred to as the IR Program.

Phase I RI (TRC 1991)

The Phase I RI field investigations were conducted from September 1989 to March 1990 and the Phase I Draft Final RI Report was submitted in May 1991. The Phase I RI included two soil borings/monitoring wells (MW07-3S and MW07-4S) located downgradient of a magnetic anomaly identified during the CS and the collection of soil samples from the two borings and ground-water samples from three wells (MW07-1S, MW07-3S, and MW07-4S) analyzed for the full Target Compound List and Target Analyte List (TCL/TAL) parameters.

Estimated concentrations of chloroform, 4,4'-DDT, and 4,4'-DDE were reported in one of the surface soil samples (B7-1), while an estimated concentration of bis(2-ethylhexyl)phthalate (220 J μg/kg) was reported from the 2 to 4 ft interval below ground surface (bgs) sample from boring B7-2. The compound 1,1,2,2-PCA was not detected in soil or ground-water samples; however, two potential degradation products of 1,1,2,2-PCA [1,2-dichloroethene (1,2-DCE) and vinyl chloride (VC)] were detected in the ground-water samples at estimated concentrations of 30 μg/L and 2 μg/L, respectively.

Metals found to be common to each surface and subsurface soil sampling location included arsenic, chromium, lead, and zinc. No depth-specific differences were observed in either the presence or concentration of these metals. Antimony and copper were detected in the ground-water samples. From the surface soil samples, only cadmium (4.7 mg/kg), calcium (5,790 mg/kg), and sodium (411 mg/kg) from sample location B07-01 exceeded the NCBC background concentrations. From the subsurface soil samples, only calcium (914 mg/kg in location B07-02, 2 to 4 ft bgs) exceeded NCBC background concentrations.

Toxicity Characteristic Leaching Procedure (TCLP) results reported that a low concentration of toluene may be leachable from the soil. TCLP extraction results also reported that copper, lead, and zinc were leachable from the soils. Polychlorinated biphenyls (PCB) were not detected in soil, ground water, or sediment. The Phase I RI recommended no further remedial action with bi-annual ground-water monitoring for Site 07.

As a result of comments and concerns from the EPA and RIDEM regarding the Phase I RI, a Phase II and Supplemental Phase II RI were performed during 1993 to 1994 to further delineate the horizontal and vertical extent of VOC associated with previous disposal activities at the site.

Phase II RI (TRC 1994)

Phase II field activities at Site 07 were conducted from December 1992 to August 1993. Geophysical investigations comprised of a seismic refraction survey, an electromagnetic conductivity (EM) survey, and a magnetometer survey, were performed to gain a better understanding of the subsurface at the Calf Pasture Point prior to drilling for the Phase II RI. The seismic refraction survey was primarily used to profile the bedrock surface below portions of the site. The EM conductivity survey was used to aid in assessing the location and/or extent of buried metallic objects (e.g., drums, tanks, metal structures), or conductive ground water. The magnetometer survey aided in distinguishing anomalies due to ferrous metal from electrically conductive, EM-identified, non-ferrous objects. The Phase II RI included:

- A soil gas survey was performed on 22 December 1992 and 12 January 1993 at thirty points in an area located just east of Bunker No. 339, and between Bunker No. 60 and wells MW07-1S, MW07-2S, and MW07-3S. VOC were detected at one sample location east of Bunker 339 at a total concentration of 12 μg/L [as "total Flame Ionization Detector (FID) VOC"]. Results of the soil gas survey provided the rational for moving a planned surface soil sampling location 07SS-8 to investigate an elevated VOC soil gas sample location.

- During January 1993, a seismic refraction survey was conducted at Site 07. Four seismic refraction geophysical survey lines were performed in the vicinity of the three bunkers and south to the vicinity of wells MW07-3S, MW07-4S, and MW07-5S (plus a line about 400 ft east of MW07-5S and one line south). The interpreted depth to the competent bedrock surface was estimated to range between 14 to 26 ft bgs and to be sloping downward from the north to the south. An assessment of the extent and thickness of highly fractured or highly weathered bedrock was unsuccessful because the refraction velocities through this zone could not be distinguished from that of the saturated soil. Therefore, only the top of competent bedrock could be identified.

- On 11 January 1993, an EM survey was performed on approximately 9.2 acres extending as far north as the bedrock outcrop and as far south as the marshlands, on a 50-ft grid using a Geonics EM-31 instrument. A small electrically conductive area was recorded near MW07-2S, corresponding to the area of buried drums discovered during the CS. The EM values ranged from 3.0 mmhos/meter in the northwest portion of the site to 68 mmhos/meter in the southeast. This gradual change in EM values was attributed to salt water intrusion into the ground water.

- A magnetometer survey was performed on 12 January 1993 along the same field location grid used for the EM survey. One of the anomalies identified during the CS was located (the same anomaly also identified by the EM survey). A test pit was planned at this location between MW07-2S and MW07-1S. Magnetometer values recorded during the survey were used to produce a magnetic contour map of the site. The magnetometer contour map indicated areas of elevated or depressed magnetometer values (with respect to background) across the site. Based on the EM and magnetometer surveys, one of the planned test pits (TR-04) was relocated to investigate the magnetic anomaly located adjacent to MW07-2S.

- From 11 to 13 May 1993, four test pit investigations were conducted, including soil sampling, to visually inspect three areas where geophysical anomalies were mapped. Test pit 1 was located adjacent to MW07-8S, test pit 2 was located adjacent to MW07-6S, test pit 3 was located adjacent to MW07-3D, and test pit 4 was located between MW07-1 and MW07-5. At three test pit locations, no evidence of soil contamination was detected. At the fourth location (TP-02), no evidence of soil contamination could be identified but the source of the geophysical anomaly could be attributed to a short length of buried metal pipe about 0.5 ft bgs, also believed to be the source of the

Confirmation Study anomaly. Low concentrations of metals were detected in the test pit samples.

- In June 1993, four shallow borings/wells (MW07-5S, MW07-6S, MW07-7S, and MW07-8S) and two deep borings/wells (MW07-3D and MW07-5D) were installed. Surface and subsurface soil samples were analyzed. Acetone (non-detect to 52 μg/kg) and 1,1,1-trichloroethane (1,1,1-TCA: non-detect to 3 J μg/kg) were detected in subsurface soil. Various metals were detected in surface and subsurface soils (see below). Analytical summary tables are provided in Appendix A-4 of the Phase III RI (EA 1998a). NX-rock cores were obtained from MW07-3D, MW07-5D, and MW07-7S.

- With respect to metals analyses in Phase II soil samples, fourteen surface soil samples and nine subsurface soil samples were collected. From the surface soil samples, cyanide (0.16 mg/kg), nickel (243 mg/kg), and thallium (0.87 mg/kg) exceeded NCBC background concentrations. From the subsurface soil samples, nine metals exceeded NCBC background levels. Seven of these were detected in the sample collected from MW07-07 (10 to 12 ft bgs) [barium (18.6 mg/kg), chromium (13.1 mg/kg), cobalt (6.1 mg/kg), iron (15,600 mg/kg), magnesium (3,250 mg/kg), nickel (10.6 mg/kg), and potassium (1,230 mg/kg)]. The remaining two metals (antimony at 3.9 mg/kg and calcium at 8,390 mg/kg) were detected in the soil samples collected from MW07-05 (4 to 6 ft bgs) and MW07-08 (4 to 6 ft bgs), respectively.

- In July 1993, analytical results of ground-water samples from Phase II monitoring wells indicated that VOC were detected in samples of both shallow and deep ground water at Site 07. 1,2-DCE and trichloroethene (TCE) were detected in 4 of 9 ground-water monitoring wells; 1,1,2,2-PCA was detected in 3 of the 9 wells which were sampled. In deep and shallow ground water, the highest total VOC concentration reported was 57,400 μg/L (MW07-5D) and 37 μg/L (MW07-2S), respectively. Analytical summary tables are provided in Appendix A-4 of the Phase III RI (EA 1998a). Based upon these results, a Supplemental Phase II investigation was performed.

<u>Supplemental Phase II RI</u>

The objectives of the Supplemental Phase II RI at Site 07 were to locate the original source area of the chlorinated-VOC detected in the Phase II RI ground-water samples as well as the horizontal extent of VOC in the downgradient deep ground water (south and east). The Supplemental Phase II RI included:

- Installation and sampling (March 1994) of twenty-one micro-wells in the general area between monitoring wells MW07-7S, MW07-1S, and MW07-2S to assess the source area for the chlorinated solvent (DANC) disposal/release. Results of the micro-well ground-water samples were used to delineate the extent of VOC in shallow ground water in the suspected disposal/release area. The highest VOC concentrations were detected in micro-wells GH-2 and GH-7 at total VOC concentrations of 776 μg/L and 318 J μg/L, respectively. These two micro-wells are located north of well MW07-2S and just south and north of the dirt road, respectively.

- Installation of five deep monitoring wells (MW07-9D through MW07-13D) in the area south of wells MW07-4S and MW07-3S toward the shoreline. These wells were drilled to refusal (bedrock was not confirmed by coring).

- Based upon the results of the micro-wells, the source area for the chlorinated-VOC detected in ground-water samples appeared to be approximately 30 to 80 ft north of well MW07-2S. A relatively small plume of dissolved chlorinated-VOC was detected in samples from wells MW07-2S and MW07-4S. Chlorinated VOC were detected in ground-water samples collected from each of the five deep wells with the highest total concentration detected in the sample collected from well MW07-9D at 5,860 μg/L. Maximum concentrations of VOC which were detected include acetone at 57 μg/L (MW07-12D), 1,2-DCE (total) at 2,800 μg/L (MW07-9D), TCE at 1,500 μg/L (MW07-9D), 1,1,2-TCA at 270 μg/L (MW07-9D), benzene at 40 J μg/L (MW07-10D), and 1,1,2,2-PCA at 1,300 μg/L (MW07-9D). Various metals were also detected in ground water. A summary table of the analytical results is provided in Appendix A-4 of the Phase III RI (EA 1998a).

The Phase II and Supplemental Phase II RI report concluded that additional information was required to define the extent of chlorinated-VOC, particularly in the bedrock.

Phase III RI (EA 1998a)

The Phase II RI report provided sufficient data to address site source control. Test pits, shallow soil borings, monitoring well installations, a soil gas survey, and revised geophysical studies were undertaken during the Phase II RI to gain a better understanding of subsurface conditions. However, there was not sufficient data regarding the nature and extent of VOC and metals in ground water, nor the behavior/migration of VOC and metals in ground water from Site 07 to Allen Harbor and Narragansett Bay. Therefore, the overall objective of the Phase III RI was the collection and evaluation of data related to further assessment of the nature and extent of TCL-VOC and TAL-metals in ground water and the behavior/migration of VOC and metals from beneath Site 07 to Allen Harbor and Narragansett Bay. The Phase III RI study area covers approximately 40 acres in the southern portion of Calf Pasture Point. The specific objectives of the Phase III RI at Site 07 were as follows:

- Evaluate the south and west horizontal extent of the shallow ground-water VOC plume identified during the Phase II RI;
- Evaluate the potential presence and character of residual and/or free-flowing dense non-aqueous phase liquid (DNAPL) in the deep soil beneath the area of Phase II RI microwells MW-GH2 and MW-GH7;

- Further evaluate the horizontal extent of the deep chlorinated-VOC plume above bedrock in the till unit and in the upper portion of the competent bedrock;
- Further evaluate the geology and hydrogeology of Site 07; and
- Assess the geology, soil, and ground-water quality offshore beneath the harbor, entrance channel, and Spink Neck.

During the Phase III RI, soil samples were not collected for SVOC, PCB/pesticide, or inorganic (metals) analyses.

The purpose of the HHRA performed in the Phase III RI was to determine whether potential human health risks would be associated with chemicals of concern (COC) in surface and subsurface soils, ground water, surface water, sediments, shellfish, and air at Site 07. Risk scenarios were evaluated associated with onsite exposures to COC by (1) future construction/remediation workers, (2) future recreational users, (3) consumers of locally caught shellfish, (4) hypothetical future residents, and (5) bather/swimmer in surface water adjacent to Site 07.

- **Upper Sand Unit**—No petroleum-VOC were detected in the soil samples from this unit. Chlorinated-VOC were detected in 4 of the 21 sampled intervals, primarily located in the northern portion of the site (MW07-04, MW07-14, MW07-17, and MW07-31). The highest concentration of total chlorinated-VOC (39,510 μg/kg) was detected in the 12 to 14 ft bgs sample from MW07-14. This soil sample was collected from the bottom of the upper sand unit and the top of the silt unit in the vicinity of the former apparent DANC disposal area. Three chlorinated-VOC were detected in that sample [1,1,2,2-PCA at 38,000 μg/kg, TCE at 1,200 μg/kg, and tetrachloroethene (PCE) at 310 μg/kg]. Total chlorinated-VOC was detected at only 33 μg/kg, 14 μg/kg, and 2 μg/kg in samples from MW07-31, MW07-04, and MW07-17, respectively, located southwest and south of MW07-14 in the northern portion of the site. Chlorinated-VOC were not detected in samples collected from the upper sand unit in the western, southern, and eastern portions of the site.

- **Silt Unit**—The only petroleum-VOC detected in the soil samples from this unit was toluene at 3 μg/kg in the sample from MW07-15 (18 to 20 ft bgs). Chlorinated-VOC were detected in 9 of 14 samples, primarily located in the northern portion of the site. The higher concentrations of total chlorinated-VOC were detected in the four samples collected from the lower (approximately) 5 ft or less of the silt unit. The concentration of total chlorinated-VOC detected in these four samples was: 52,000 μg/kg for MW07-05 (39 to 41 ft bgs); 34,000 μg/kg for MW07-04 (29 to 31 ft bgs); 25,700 μg/kg for SB07-02 (28 to 30 ft bgs); and 16,390 μg/kg for MW07-14 (22 to 24 ft bgs). 1,1,2,2-PCA and TCE were the main VOC detected in these four samples. MW07-14 is located within the apparent vicinity of the former DANC disposal area, while MW07-04, MW07-05, and SB07-02 are located approximately 200 ft southwest of MW07-14. Additionally, 5,155 μg/kg of total chlorinated-VOC [5,000 μg/kg (97%) of which was 1,1,2,2-PCA] was detected in the sandy silt facies of this unit which is also located within the apparent vicinity of the former DANC disposal area. Chlorinated-VOC were not detected in samples collected from this unit in the northwestern (MW07-22), northeastern (MW07-28), and southern (MW07-18 and MW07-20) portions of the site.

- **Lower Sand and Till Units**—The only petroleum-VOC detected in these samples was toluene at 1 μg/kg (MW07-19, 16 to 18 ft bgs) and 2 μg/kg (MW07-21, 37 to 39 ft bgs). Chlorinated-VOC were detected in 22 of the 35 samples collected. These 22 samples are generally located in an area that extends from the area of highest total chlorinated-VOC concentrations (the MW07-05 and MW07-31 area) southwest to MW07-21 and MW07-23. The higher concentrations of total chlorinated-VOC were detected in four samples that are located within the apparent former DANC disposal area (MW07-31), and approximately 125 to 250 ft south (MW07-05, SB07-01, and MW07-17). The concentration of total chlorinated-VOC detected in these four samples is: 48,400 μg/kg for MW07-05 (44 to 46 ft bgs); 21,259 μg/kg for MW07-31 (24 to 25 ft bgs); 13,880 μg/kg for SB07-01 (43 to 44.5 ft bgs); and 12,960 μg/kg for MW07-17 (44 to 46 ft bgs). 1,1,2,2-PCA and TCE were the main chlorinated-VOC detected in these four samples. Chlorinated-VOC were not detected in samples collected from the lower sand and till units in the northwestern (MW07-22) and eastern to southern (MW07-16, -18, -20, -24, -29, and -30) portions of the site.

- **VOC in Shallow Ground Water**—Chlorinated-VOC were detected in samples collected from 5 of the 17 shallow wells (and in one of the screening samples from the mid-harbor borings at a trace concentration which does not appear to be related to Site 07: EA 1998a, 1998b). Based upon the Phase III RI data, there appear to be two separate chlorinated-VOC plumes in shallow ground water (Figure 1-19). The first plume has relatively low concentrations of total chlorinated-VOC and is located in the vicinity of the former DANC disposal area (MW07-01S; 23 μg/L and MW07-02S; 1 μg/L). The data indicate that release of 1,1,2,2-PCA (a major component of DANC) from the former DANC disposal area appears to have migrated vertically downward through a locally present sandy facies of the underlying silt unit rather than laterally. This chlorinated-VOC plume in shallow ground water is small and is surrounded by wells where chlorinated-VOC were non-detect. The second plume has higher concentrations of total chlorinated-VOC and is located in the southwestern portion of the site (MW07-19S; 5,950 μg/L, MW07-21S; 1,481 μg/L, and MW07-26S; 1,483 μg/L). There are no reported disposal activities in that portion of the site. The second plume may be an extension of the plume in deep ground water due to the impact on ground-water flow from a salt water "wedge" located south of the site.

- **VOC in Deep Ground Water**—Chlorinated-VOC were detected in samples from 16 of the 25 deep wells. The sixteen wells are generally located in the western portion of the site (Figure 1-20). The available data suggest the presence of one plume in the deep ground-water (generally in the till which directly overlies bedrock). The highest total chlorinated-VOC concentrations detected in this plume include four wells which are located just south of the vicinity of the apparent former DANC disposal area and within an interpreted valley in the underlying bedrock surface: MW07-17D (193,680 μg/L), MW07-04D (123,000 μg/L), MW07-05D (96,750 μg/L), and MW07-15D (93,890 μg/L). MW07-05D and MW07-17D appear to be located along the base of the northwest-southeast trending valley in the bedrock surface. Dissolved chlorinated-VOC concentrations detected in deep ground water (till unit, lower sand unit, and lower portion of the silt unit) decrease to non-detect toward the east and south shoreline with Narragansett Bay. The west and southwest extent of the chlorinated-VOC in deep ground water continues beneath the site shoreline with Allen Harbor and the entrance channel; however, chlorinated VOC were not detected across the entrance channel at Spink Neck (MW07-32D) or in the mid-harbor borings to the southwest (SB09-16 and SB09-17).

In the approximate vicinity of MW07-27D, the deep VOC plume appears to split, one branch continuing down into bedrock and the other extending upward through MW07-19S and MW07-21S perhaps related to ground-water flow up over the salt water wedge located just offshore.

- **VOC in Bedrock Ground Water**—Chlorinated-VOC were detected in samples from 3 of the 6 bedrock wells (Figure 1-21). Chlorinated-VOC were not detected in the central (MW07-09R) or eastern (MW07-16R) portions of Site 07. Chlorinated VOC also were not detected across the entrance channel of Allen Harbor at Spink Neck (MW07-32R). The highest concentration of total chlorinated-VOC (41,730 μg/L) was detected in the sample from MW07-05R. MW07-05R is located approximately 150 ft southwest of the apparent vicinity of the former DANC disposal area which occurred at ground surface. Additionally, MW07-05R is located in an apparent valley in the bedrock surface into which the original DANC release may have migrated through the overlying till unit. The data suggest the presence of a dissolved chlorinated-VOC plume in the bedrock ground-water zone from the vicinity of MW07-05R. Related ground-water and VOC flow is probably through fractures in the bedrock and through the overlying till unit which appears to be in direct hydraulic connection with the bedrock.

- **Metals in Ground Water**—In ground-water samples, only thallium was detected above its Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCL) and only iron and manganese were above their respective Secondary (non-enforceable) Maximum Contaminant Levels (SMCL). The iron concentrations detected in most of the Phase III RI ground-water samples were below the NCBC background concentration of 25,500 μg/L. The manganese concentrations detected in most of the Phase III RI ground-water samples were below the NCBC background concentration of 3,292 μg/L. [Background concentrations are presented in the Basewide Ground-Water Inorganics Study Report (Stone & Webster 1996) - see Table 2-5.] The thallium concentrations detected in the Phase III RI ground-water samples were mostly below background levels (4.1 μg/L) and the rest were below the 32 μg/L concentration detected in the water samples from Allen Harbor (NCBC-AH1) and Narragansett Bay (NCBC-NB1).

In early 1998, the Navy installed two additional ground-water monitoring wells on the northern tip of Spink Neck (MW07-32D and MW07-32R) (EA 1998b). The wells are located across Allen Harbor's entrance channel from Calf Pasture Point and are screened in the intervals just above competent (i.e., solid) bedrock and in the upper portion of competent bedrock. Ground-water samples from the two wells were analyzed for VOC to assess whether the Site 07 plume has impacted the Spink Neck area. The VOC COC from the Site 07 plume were not detected in the samples from the Spink Neck wells (Figures 1-20 and 1-21).

Samples of ground water were also collected from two mid-harbor borings, SB09-16 and SB09-17, located southwest of Site 07. Only trace levels of some VOC and metals were detected in the samples (Figures 1-19 and 1-20). The new data combined with the existing data do not indicate the presence of a plume from Site 07 under Allen Harbor (EA 1998a).

Chlorinated VOC were not detected in the offshore, mid-harbor soil samples (SB09-16 and SB09-17) or the Spink Neck soil sample locations (MW07-32D and -32R).

The Phase III RI recommended no further action with long-term monitoring.

1.2.3.4 Study Area Screening Evaluation (Halliburton NUS 1994)

Beginning in June 1993 (prior to the completion of the Phase II RI), the "Study Area Screening Evaluation" was performed to investigate the Munitions Bunkers at Calf Pasture Point and to assess whether releases of previously stored materials may have affected the interiors of the bunkers, to determine if the concrete bunker floors were cracked (thus providing possible pathways for any related releases), and to determine the presence of wastes reportedly buried next to one of the bunkers.

Assessment of the interior of the bunkers found no cracks in the floors. Some staining was observed and wipe samples were obtained from the inside surfaces of the bunkers. Four wipe samples were collected from each bunker and analyzed for TCL-SVOC, pesticide/PCB, and TAL inorganic analytes. Six organic compounds and twelve inorganic analytes were detected in wipe samples of which the highest detected concentrations exceeded the proposed New Jersey clean up standards and Rhode Island lead standards. (New Jersey clean-up standards were considered because, at that time, Rhode Island did not have clean-up criteria for wipe sample constituents other than lead and PCB.) Because no release pathway was identified, it was concluded that there was no apparent impact on Site 07.

Magnetic and electrical conductivity geophysical investigations were conducted at each bunker and test pits were excavated near Bunker 60. Anomalies were detected near each of the bunkers. However, these anomalies were attributed to steel on the roof of each bunker. No buried containers were found.

Seven test pits were excavated. No buried wastes, discolored soil, or other signs of contamination were found. Methylene chloride (a common laboratory contaminant) was detected in 10 of 12 subsurface soil samples.

The Navy evaluated and cleaned up lead dust during January through March 1997 for Bunkers 59 and 60. The doors to Bunkers 59 and 60 were welded shut during March 1997. The Navy demolished Bunker 339 in February 1997. A Close-Out Report was issued in October 1997 (Foster Wheeler 1997).

1.2.3.5 Ecological Risk Assessments

The impact of Site 07 on Allen Harbor and the terrestrial ecology were addressed by the "Allen Harbor Landfill and Calf Pasture Point Marine Ecological Risk Assessment" (Marine ERA) (EA 1996a) and the "Facility-Wide Freshwater/Terrestrial Ecological Risk Assessment" (EA 1996b), respectively.

During the Marine ERA, a "weight of evidence" approach was used to assess potential ecological risks to biological communities of intertidal and subtidal habitats of Allen Harbor in accordance with EPA guidance documents. The approach was based on evaluation of constituent analytical data relative to environmental benchmarks, direct field observations, and selected field and laboratory studies from the scientific literature. The essential components of the marine ERA included:

- *Problem Formulation:* This involved identification of affected media and COC, evaluation of the spatial extent of COC, identification of the ecological receptors potentially at risk from COC, and identification of appropriate assessment endpoints (resources to be protected) and measurement endpoints (parameters used to status resource condition). The information was integrated into a conceptual model which identified the possible exposure scenarios and mechanisms of ecological impact.

- *Exposure and Ecological Effects Characterization.* This included collection of information to quantify chemical exposures and observed or predicted ecological effects resulting from exposure. Exposure Assessment involved quantification/estimation of the concentrations of COC in environmental media in the exposure pathways from source to ecological receptors. Ecological Effects Assessment involved a combination of toxicological literature review, *in-situ* characterizations of the status of receptor species, toxicity evaluations of exposure media, and modeling exercises to predict the occurrence of adverse ecological impact.

- *Risk Characterization.* This represented a weight-of-evidence approach involving comparisons of apparent adverse impacts with conditions at reference stations, analysis of COC concentrations vs. observations of adverse effects, analysis of COC bioaccumulation and related impacts on biota, comparisons of toxicity evaluations with observed ecological effects, comparisons of COC concentrations in sediments and water with reference site concentrations, and comparisons of COC concentrations with published benchmarks for toxicity of the COC.

During the Marine ERA and the Risk Assessment Pilot Studies in Allen Harbor, several sediment and shellfish samples were collected along the western and southern shoreline of Calf Pasture Point (Tables 2-6 and 2-7). The majority of these samples were collected in potential areas where shallow ground water from Site 07 enters Allen Harbor and the entrance channel. VOC (the COC at Site 07) were not identified as COC in either the shoreline sediment or shellfish samples.

The Freshwater/Terrestrial ERA for Calf Pasture Point was performed as part of an Allen Harbor Watershed study. The Calf Pasture Point study area included intertidal wetland, disturbed meadows and thickets of shrubs, and fields comprised of dominant habitats. A large number of bird species are present including marine, wetland, and upland taxa. Many species breed onsite despite large areas of recently disturbed habitat. The freshwater/terrestrial ERA quantified chemical exposure to representative receptors of concern potentially present within Allen Harbor watershed and within specific habitats in each watershed. Under the weight-of-evidence approach employed in conducting this assessment, supporting information regarding wetlands functional valves, biotic populations and communities, and observational data on wildlife was obtained. The risk assessment was based on biotic and abiotic data collected by TRC, EA, and SAIC.

The results of the Facility-Wide Freshwater/Terrestrial ERA indicated that there is no terrestrial ecological risk from Site 07 surface soil. The results of the Marine ERA indicated that, regarding potential risk to the marine ecology, a cause-and-effect relationship could not be established for Site 07.

During December 1997, EPA collected additional sediment samples from the interior wetlands area (near MW07-13S and -19S) and analyzed the samples for VOC. Only trace concentrations of VOC were detected in a few samples and no unacceptable risk was identified from VOC in shallow ground water potentially discharging to these areas.

1.2.3.6 Feasibility Studies

The first step of the FS process, the Initial Screening of Alternatives (TRC 1993) was conducted for Site 07 on the basis of Phase I RI information only. A Draft Detailed Analysis of Alternatives (DAA) (TRC 1994) included information obtained during the Phase II RI. For the remediation of ground water, the Draft DAA evaluated No Action, Limited Action (institutional control and long term monitoring), Extraction (with air stripping/chemical precipitation and discharge to surface water), Extraction (with cross-flow pervaporation/ electrochemical treatment and discharge to surface water), and *In-Situ* Treatment (permeable reaction wall). The overall recommended alternative was ground-water extraction from shallow and deep zones, treatment with air stripping and chemical precipitation, discharge to surface water, deed restrictions, and long-term monitoring.

The DAA was discontinued due to gaps in the database. Subsequently, the Phase III RI was initiated to further investigate deep and bedrock ground water. The FS presented in this report includes information from the Phase III RI and ERA. This FS supersedes the 1994 DAA.

1.3 PHYSICAL CHARACTERISTICS OF STUDY AREA

1.3.1 Climate Characterization

Given the coastal proximity of NCBC Davisville, weather patterns are continuously modified by the dynamic effects of the Narragansett Bay and the Atlantic Ocean. The average annual wind speed over the area is 10.6 miles per hour (mph) with a prevailing southwesterly direction. In the winter, the average temperature is 30°F and average daily minimum temperature is 20°F. In the summer, the average temperature is 70°F and average daily maximum is 80°F.

The average annual precipitation for the area is 45.32 in., as measured for the period of 1951 through 1980. Historically, June has been the driest month with an average of 2.79 in. of precipitation, whereas December, averaging 4.47 in., has been the wettest.

1.3.2 Regional Geology

NCBC Davisville is located within the Narragansett Basin, a complex structural syncline approximately 12 miles wide and with up to 12,000 ft of accumulated sediment deposited within this feature (Figure 1-5). The Narragansett Basin's western limit is approximately 3 miles west of NCBC Davisville, and its eastern edge is close to Fall River, Massachusetts. All of the NCBC Davisville sites, with the exception of Site 10 (Camp Fogarty), overlie a portion of the Narragansett Basin. The bedrock is overlain by various glacial deposits up to 200 ft thick that have left the basin relatively flat compared to the surrounding areas (Schafer 1961). According to Williams (1964) and USDA (1981), the principle bedrock unit in the vicinity of NCBC Davisville is the Pennsylvanian age undifferentiated Rhode Island Formation. In the vicinity of NCBC Davisville, the depth to bedrock ranges from approximately 55 ft above site grade at the rock outcrop at Calf Pasture Point (just north of Site 07) to 84.5 ft bgs at MW07-16D located along the east coast of Site 07.

1.3.3 Regional Ground-Water Hydrogeology

The State of Rhode Island is divided into five drainage basins: the Narragansett Bay Basin, the Pawtucket River Basin, the Rhode Island Coastal Basin, the Thames River Basin, and the Massachusetts Coastal Basin. NCBC Davisville lies within the Narragansett Bay Basin (NBB), the largest and most hydrogeologically significant basin in the state. The NBB covers approximately two-thirds of the state and includes a system of waterways that discharge into the Atlantic Ocean between Point Judith and Sakonnet Point. The NBB includes Narragansett Bay and its entire shoreline, the drainage system of three major rivers (Taunton, Blackstone, and Pawtuxet), and a number of small rivers and streams that drain into Narragansett Bay

(USDA 1981). Within each drainage basin, smaller sub-basins may be defined based on significant streams, tributaries, and reservoirs.

Rhode Island's abundant precipitation, numerous perennial streams, lakes, and reservoirs provide a significant surface supply of fresh water for the state's industry and domestic consumption. Additionally, three primary aquifers provide fresh ground water for the state. In 1985, the total fresh-water withdrawals in Rhode Island were 147 million gallons per day (MGD). Of this, approximately 69% was for domestic and commercial use, 27% was for industrial and mining use, and 4% was for agricultural use. About 81.5% of the fresh water was obtained from surface water sources and the remaining 18.5% was from ground water. The Scituate Reservoir in Providence County accounts for more than 80% of the reservoir storage capacity in Rhode Island. About 76% of the State's population receives its drinking water from the Rhode Island reservoir system. The remaining 24% obtain potable water from public supply wells (USGS 1989).

USGS Water Supply Paper 1779 (Rosenshein 1968) describes the aquifer characteristics of the Potowomut-Wickford area of south-central Rhode Island. That study area comprises approximately 60 square miles from East Greenwich to the southern tip of North Kingstown and west into parts of West Greenwich, Rhode Island. NCBC Davisville is located in the east-central part of that area. The Potowomut-Wickford area comprises parts of five river basins; however, only three basins display major hydrogeologic significance. The three primary basins include the Potowomut River Basin, the Annaquatucket River Basin, and the Pettaquamscutt River Basin. All three basins are situated west and/or southwest of NCBC Davisville.

The primary aquifer of the Potowomut-Wickford area is the Potowomut-Wickford Aquifer, producing water primarily from the stratified drift unit. That area of ground-water supply production is located generally within a northeast trending valley in the bedrock surface located about 2.5 miles west and northwest of Site 07. However, the portion developed for municipal ground-water supply is separated from Site 07 by a ridge in the bedrock surface located west and northwest of Site 07. The Potowomut-Wickford Aquifer is not present on that ridge.

1.3.4 Site Topography

NCBC Davisville is located on the Seaboard Lowland coastal belt of the New England physiographic province (Fenneman 1938), and within the Narragansett Basin of metamorphosed sedimentary rocks of Pennsylvanian age. The surface topography near NCBC Davisville (from Quonset Point to a point approximately 5 miles west of Quonset Point) exhibits over 150 ft of relief in a series of north-south trending valleys and ridges (Williams 1964) (Figure 1-2). These valleys were developed by river and stream erosion and deepened by the glacial activity. Surface drainage is not well developed, and swamps and marshes are extensive. Streams are small and, in most places, bordered by swamps.

The land surface at NCBC Davisville has undergone significant modification (i.e., hills were leveled and depressions filled in as part of the original construction of the Base). The elevation of the ground surface at Site 07 ranges from MSL along the beaches to about 55 ft above MSL at the bedrock outcrop (Figure 1-6). The site is currently overgrown with a mixture of shrubs, small trees, and grasses.

South from well cluster MW07-05, the surface topography slopes gently from approximately 10 ft above MSL to sea level at the shoreline. North from MW07-05, the ground surface rises to an elevation of approximately 19 ft above MSL at MW07-07S. North of MW07-07S is the previously noted prominent hill where bedrock is exposed.

1.3.5 Local Geology

The results of the Phase III field investigation and previous investigations, show that the geology at Site 07 is characterized by anthropogenic fill (dredged material) and Quaternary (Pleistocene) glacial deposits mantling quartzite bedrock of the Pennsylvanian age undifferentiated Rhode Island Formation. Based upon the Phase I, II, and III RI logs of borings, Site 07 is underlain by five main stratigraphic units (listed from the ground surface to bedrock):

(1) the upper sand unit, a brown to gray sand with varying amounts of silt and gravel and occasional shell fragments, and an occasional layer sand and silt facies encountered by only five borings/wells (beneath the harbor, this interval is represented by organic silt and sand that forms the harbor floor);
(2) the silt unit which is present beneath Allen Harbor and most of the site except north in the vicinity of the bedrock outcrop and south in the vicinity of MW07-26S, 19S, 21S, and 32D/R. Where present along with an upward vertical ground-water flow gradient, the silt unit impedes the upward flow of ground water and the migration of chlorinated VOC from the deep zones;
(3) the lower sand unit, consisting of very fine to medium sand with varying amounts of silt and encountered only beneath the eastern portion of the site;
(4) the till unit, silty gravelly sand to sandy gravelly silt which was encountered beneath the harbor and the site; and
(5) quartzite, phyllite, and gneissic bedrock which was encountered beneath the harbor and the site.

Figure 1-7 illustrates the location of geologic cross-sections developed during the Phase III RI. Figures 1-8 through 1-14b depict geologic cross-sections illustrating the generalized distribution and thickness of subsurface features from selected borings at Site 07. Based upon the Phase I, II, and III RI boring/well data, the interpretive geological cross sections show the general lateral extent and thickness of the soil units.

The upper sand unit consists mostly of fine to coarse sand with varying amounts of silt and occasional shell fragments or gravel. Thickness of this unit ranges from 4.5 ft (MW07-23D) to 18.5 ft (MW07-24D). The layered sand and silt facies was encountered only at the following five borings/wells: MW07-02, MW07-09, MW07-24, MW07-31, and SB07-02.

The silt unit directly underlies the upper sand unit. The upper surface of the gray silt unit ranges from 3.4 ft (MW07-22S) above MSL to 14.1 ft (MW09-24D) below MSL, with a maximum thickness of approximately 36 ft at MW07-29D. The silt unit is not present in two general areas: in the vicinity of exposed bedrock (just north of the site) and in the southwestern portion of the site at MW07-19, MW07-21, MW07-26 (where the till unit extends up to within about 5 ft of ground surface) and MW07-32D/R. The lower portion of this unit is sandy silt at MW07-16 and MW07-20. At MW07-31I and SB07-03 (the vicinity of the DANC disposal), nearly all of this unit is sandy silt. At three borings/wells (MW07-16, MW07-18, and MW07-20) in the eastern portion of the site, this unit is generally a clayey silt.

The lower sand unit is comprised of very fine to fine sand with varying amounts of silt and occasional gravel or medium to coarse sand. The lower sand unit was encountered only beneath the eastern to southeastern portion of the site (MW07-09, -11, -16, -17, -18, -20, -29, and -30) and directly underlies the gray silt unit in areas where the elevation of the top of the till unit is less than –35 ft MSL. The maximum thickness of this unit was 28.2 ft (MW07-30D).

The till unit underlies the gray silt unit (or lower sand unit when present) and is typically comprised of a silty-gravelly sand (Figures 1-8 through 1-14b). However, in some areas, the till is a sandy gravelly silt [e.g., beneath some northern and western portions of the site (MW07-14D and SB07-03, MW07-04D and SB07-02, and MW07-10D, -12D, and -26S) and beneath the eastern corner of the site (MW07-16D, -29D, and -30D)]. Till was encountered in the deep well borings except for MW07-11D. The top of the till unit ranges from 11.7 ft above MSL (MW07-07S) in the north corner of the site to 66.2 ft below MSL (MW07-18D) in the southeastern portion of the site. Additionally, in the southwestern portion of the site, the till is within approximately 5 ft of ground surface forming a hill with 15 to 30 ft of relief and is approximately 31 to 36 ft thick. The thickness of the till beneath other areas of the site is generally less than 12 ft.

Bedrock is comprised of quartzite with varying amounts of fracturing and some zones of phyllite and gneiss. Lengths of core were obtained from the Phase III RI deep wells (5 ft to confirm the presence of competent rock) and from the wells screened in rock. The 5-ft cores related to the deep wells showed multiple fractures, with the exception of MW07-16D which had no apparent open fractures and MW07-04D and MW07-20D which each had only one apparent open fracture. For the cores from the rock wells, those from MW07-05R, MW07-16R, and MW07-25R showed minimal fracturing, while those from MW07-09R and MW07-21R had considerably more fracturing. Bedrock was encountered in the borings at depths ranging from approximately 16 to 84.5 ft bgs. Bedrock crops out at the center of Calf Pasture Point, just north of the site, with the top of the outcrop at an approximate elevation of 57 ft above MSL. In general, the bedrock surface beneath the site slopes downward from –15 to

−25 ft MSL in the western area to a maximum depth of −78.4 ft MSL at MW07-16 and MW07-30 (Figure 1-15). Figure 1-15 further shows that there is an apparent localized valley in the bedrock surface which extends southeast from well cluster MW07-05 which then intersects the east trending valley or general surface slope just south of MW07-09.

1.3.6 Local Hydrogeology

Ground water under Site 07 is classified as "GB" by RIDEM. Class GB ground water is considered to be unsuitable for public or private drinking water use without treatment. The four Site 07 subsurface soil strata, plus bedrock, have been divided into the following three hydrogeological zones:

> Shallow Ground-Water Zone - The shallow ground-water zone is the saturated portion of the upper sand unit which is under unconfined conditions, and includes ground-water table data from the shallow (S) wells. The shallow ground-water zone may extend a short distance under portions of the adjacent bay, harbor, and entrance channel, but ends abruptly north of Site 07 where bedrock is exposed at ground surface. In the southern portion of the site in the vicinity of wells MW07-19S/D, MW07-21S/D/R, and MW07-26S, the silt unit is not present and the upper portion of the till unit extends to within approximately 5 to 8 ft of ground surface. Therefore, in that area, the shallow ground-water zone also includes the upper portion of the till unit.
>
> Shallow ground water flows approximately radially from a the bedrock hill (located just north of the site) toward the nearest shoreline for each of the three tidal stages. Figure 1-16 depicts the shallow ground-water flow regime during low tide at Site 07. As shown in the Phase III RI, shallow ground-water flow patterns during mid- and high tide are similar.
>
> Deep Ground-Water Zone - The deep ground-water zone is the lower portion of the silt unit, the lower sand unit (where present), and the till unit which respond like a confined aquifer. This includes ground-water potentiometric water surface data from the deep (D) wells which have screens set in those units or portions of units. The deep ground-water zone appears to extend in all directions from the site except to the north where it ends abruptly in the vicinity where bedrock is exposed at ground surface. Additionally, the silt unit is not present at wells MW07-19S/D, MW07-21S/D/R, and MW07-26S in the southern portion of the site. However, the till unit thickens to more than 30 ft and the upper portion of the till unit extends to within approximately 5 to 8 ft of ground surface. Therefore, in that area, the shallow and deep ground-water zones are not separated by the silt unit, but rather, are the upper and lower portions, respectively, of the till unit.
>
> Figure 1-17 depicts the deep ground-water flow regime during low tide at Site 07. As shown in the Phase III RI, deep ground-water flow patterns during mid- and high tide are similar.

Bedrock Ground-Water Zone - The bedrock ground-water zone is the upper 25 to 30 ft of competent (solid) bedrock which responds like a confined aquifer and includes potentiometric water surface data from rock (R) wells with screens set approximately 15 to 25 ft below the top of competent bedrock.

Figure 1-18 depicts the bedrock ground-water flow regime during low tide at Site 07. As shown in the Phase III RI, bedrock ground-water flow patterns during mid- and high tide are similar.

As part of the Phase III RI, a ground-water level and tidal monitoring program was performed to obtain data with which to estimate the hydraulic conductivity of the lower part of the silt unit, the lower sand unit (where present), the till unit, and the upper 25 to 30 ft of the bedrock unit and to provide continuous water-level measurements during the tidal cycles (i.e., low, mid, and high tide) for at least a 48-hour period. The tide cycles will have their greatest impact on ground-water flow in the upper sand unit (shallow ground-water zone) because the harbor and bay are adjacent to this unit. However, the tidal impact on ground-water flow in this unit is minor. The lower part of the silt, the till, and bedrock units, which do not have direct horizontal flow contact with the bay or harbor at Site 07, are impacted even less than the shallow ground-water zone. The estimated vertical permeability is substantially less than the horizontal permeability resulting in only a very small vertically downward or upward ground-water flow component between upper and lower units. Changing tide levels will affect the ground-water levels and ground-water flow in the shallow zone (upper sand unit) at the shoreline with the harbor and bay. Ground water and harbor/bay water will mix in this unit in the immediate area near the shoreline. The distance inland from the shoreline that this feature occurs is limited.

Based upon the salinity concentrations detected in the Phase III RI and offshore investigation ground-water samples, the ground water in the shallow, deep, and bedrock ground-water zones beneath Site 07 appears to be:

- saline [greater than 10 parts per thousand (‰) salinity] beneath the eastern portion (Narragansett Bay side) of the site, the northern portion of Spink Neck, and the eastern portion of the harbor (near SB09-17);
- brackish (0.5 to 10‰ salinity) beneath the central and southern portion of the site (which includes most of the VOC plume in deep ground water) and the central portion of the harbor (SB09-16); and
- fresh (less than 0.5‰ salinity) beneath the northern to northwestern portion of the site which includes the former DANC disposal area.

Based upon these data, a higher density salt water "wedge" appears to be present beneath the eastern portion of the site, near the southern shoreline of the site south to the northern portion of Spink Neck, and west to the eastern portion of the harbor. The salinity and COC data suggest that fresh and brackish (lower density) ground water from the northern portion of the site may flow up over the more dense salt water wedge to the southern portion of the site and discharge into the surface water within the zone that is a few hundred feet from the shoreline (EA 1998a). The areas of brackish and saline ground water detected in the shallow zone beneath the site approximately correspond to the surficial portion of Site 07 which, prior to 1940, was part of Allen Harbor. Between 1942 and 1943, that area was filled with saline dredge material from the Navy's construction of the pier area along the Narragansett Bay shoreline south of Site 07.

1.3.7 Wetlands and Ecological Setting

Calf Pasture Point is located within the Allen Harbor Watershed. The Allen Harbor Watershed also includes Site 09 (Allen Harbor Landfill), salt marshes adjacent to Site 09, upgradient salt and freshwater marshes, and open water areas immediately north of the landfill. Allen Harbor is an estuarine embayment of the larger Narragansett Bay marine system and is connected to Narragansett Bay by a narrow, dredged channel.

Calf Pasture Point provides diverse habitats including a fringing intertidal marsh and wetlands, early primary successional meadows with plantings, a sand beach, isolated wetlands, and a dense thicket of secondary growth and shrubs. The area is mostly planted with white pine, tamarack, red cedar, and Russian olive. The area supports early successional species, such as lichens and bryophytes which cover physically disturbed ground. The only sign of stressed vegetation was a scattered rush on the red cedar, which is common to this plant. The avian fauna reflect the diversity of habitat. Forty-four bird species have been observed on Calf Pasture Point, including wetland, marine, and upland species.

The only benthos on the point occur in the intertidal areas. Observed species include: a small Spartina marsh at the water's edge; shells of limpets (*Crepidula sp.*), softshell clams (*Mya Arenaria sp.*), and oysters (*Crassostrea sp.*); live marine snails (*Nassariou sp.*); periwinkles (*Littorina sp.*); hermit crabs (*Paguridae sp.*); hardshell clams (*Mercenaria sp.*); and fiddler crab (*Uca sp.*) burrows.

The State of Rhode Island conducted an endangered species survey of East Davisville, also referred to as the Main Center. It describes the area as having fringing saline and brackish marsh which does not provide suitable habitat for rare species, and upland areas which are slowly reverting to natural communities of shrubs.

Five isolated wetland depressions identified in the eastern portion of Calf Pasture Point were assessed to be of limited functional value, based on their isolated nature, limited size and limited vegetational diversity in relation to nearby wetland areas. The Allen Harbor and Narragansett Bay tributary wetlands were considered to be most important with respect to pollutant reduction functions (i.e., sediment stabilization, sediment/toxicant retention, and nutrient removal/transformation), production export, and aquatic and wildlife diversity/abundance. Due to the wetlands' "tight" silty/organic sandy top soil, perched ground water may maintain the wetland conditions and ground-water recharge/discharge functions are not likely to be significant.

1.4 PRESENTATION OF FINDINGS AND CONCLUSIONS OF PREVIOUS INVESTIGATIONS

1.4.1 Volatile Organic Compounds

Onsite, VOC (predominantly chlorinated compounds) were detected in soil and ground-water samples (petroleum-related VOC such as benzene and toluene were infrequently detected and typically at low concentrations—acetone detected in soil and ground water appears to have been an artifact of the decontamination procedures used during sample collection). The highest concentrations of total chlorinated VOC in soil were generally detected in the lower sand and till units in areas corresponding to the chlorinated VOC plume identified in ground water. In ground water, a plume of chlorinated VOC has been detected which affects shallow, deep, and bedrock ground water (Figures 1-19 through 1-21). The highest total chlorinated-VOC concentrations detected in this plume include four wells which are located just south of the vicinity of the apparent former DANC disposal area and within an interpreted valley in the underlying bedrock surface: MW07-17D (193,680 μg/L), MW07-04D (123,000 μg/L), MW07-05D (96,750 μg/L), and MW07-15D (93,890 μg/L). There appears to be two locations where the plume(s) was detected in shallow ground water; the first area has relatively low concentrations of total chlorinated-VOC and is located in the vicinity of the former DANC disposal area (MW07-01S; 23 μg/L and MW07-02S; 1 μg/L) and the second area has higher concentrations of total chlorinated-VOC and is located in the southwestern portion of the site (MW07-19S; 5,950 μg/L, MW07-21S; 1,481 μg/L, and MW07-26S; 1,483 μg/L). In bedrock ground water, the highest concentration of total chlorinated-VOC (41,730 μg/L) was detected in the sample from MW07-05R located approximately 150 ft southwest of the apparent vicinity of the former DANC disposal area which occurred at ground surface. A discussion of the transport and fate of the chlorinated VOC plume at Site 07 is presented in Section 1.4.6.1.

Downgradient shoreline sediment samples included W11, W12, and D14 along the western shoreline and W13, W14, D11, D12, and D13 along the southern shoreline. Downgradient intertidal wetland samples V3 and V4 are located south of MW07-12D and MW07-21S, respectively. Of the volatile COC identified at Site 07, only 1,2-DCA was detected in offshore sediment or intertidal wetland samples (in sample W-14 at 0.15 J μg/kg). This concentration does not appear to be the result of VOC concentrations in Site 07 ground water because 1,2-DCA and related chlorinated VOC were non-detect in sediment/wetland samples (W13 and V4) located between W14 and Site 07. As described in Section 1.2.3.3, the data from the additional monitoring wells at Spink Neck and the mid-harbor borings do not indicate the presence of a VOC plume from Site 07 under Allen Harbor. Although there is a ground-water pathway from the site to offshore sediment and intertidal wetland areas, no unacceptable risks have been identified in sediment/wetlands due to the Site 07 COC.

1.4.2 Semi-Volatile Organic Compounds

During the Phase I RI, only a low concentration of bis(2-ethylhexyl)phthalate (220 J μg/kg) was reported from 2 to 4 ft bgs in one subsurface soil sample (B7-2). No SVOC were detected in surface soil or ground-water samples. Samples were not analyzed for SVOC during the Phase II or III RI.

Various SVOC were detected in offshore media (shoreline sediment and shellfish); however, SVOC are not associated with Site 07 media.

1.4.3 Pesticides

During the Phase I RI, only low concentrations of 4,4'-DDT (22 μg/kg) and 4,4'-DDE (19 μg/kg) were reported in one surface soil sample (B7-1). No pesticides were detected in subsurface soil or ground-water samples. Samples were not analyzed for pesticides during the Phase II or III RI.

Various pesticides were detected in offshore media (shoreline sediment and shellfish); however, pesticides are not associated with Site 07 media.

1.4.4 PCB

During the Phase I RI, PCB were not detected in Site 07 soil, ground water, or sediment. Samples were not analyzed for PCB during the Phase II or III RI.

Various PCB were detected in offshore media (shoreline sediment and shellfish); however, PCB are not associated with Site 07 media.

1.4.5 Metals

During the Phase I RI, metals found to be common to each surface and subsurface soil sampling location included arsenic, chromium, lead, and zinc. No depth-specific differences were observed in either the presence or concentration of these metals. Antimony and copper were detected in Phase I ground-water samples. During the Phase II RI, various metals were reported in surface soil, subsurface soil, and ground water. During the Phase III RI, soil samples were not collected for metals analyses.

In ground-water samples from the Phase I, II, and III RI, various metals were detected above NCBC Davisville background levels (see Table 2-5) and a few of these were above drinking water MCL (see Table 2-4). This is likely due to sampling techniques, the locations of background wells, and the location/nature of Site 07 soil with respect to the marine environment. First, ground-water samples during the Phase I and II RI were collected using high-flow sampling techniques. Lower concentrations of some metals were reported during the Phase III which used a more representative, low-flow sampling technique. The metals which were above MCL in Phase III RI samples were within NCBC Davisville background levels. Second, Site 07 is located along a marine coastline as opposed to the basewide background wells which were located further inland at NCBC Davisville (and, therefore, may be less representative of the background conditions at Calf Pasture Point). Site 07 soil is largely comprised of dredged marine sediment. The marine influence on Site 07 soil is evidenced by the high sodium concentrations (as well as other components of marine salts such as potassium, calcium, and magnesium). Of the elevated levels of metals identified in Site 07 ground water, the Human Health Risk Assessment (HHRA) determined that only arsenic posed unacceptable risk via ingestion of ground water by residential populations (Section 1.4.5). However, only one ground-water sample from the Phase I, II, and III RI had arsenic detected (63.5 μg/L in MW07-09D) above drinking water MCL (50 μg/L) (note: a duplicate from MW07-09D had a detected arsenic concentration below the MCL).

Various metals were detected in offshore media (shoreline sediment and shellfish); however, no unacceptable risks have been identified in offshore media/receptors due to onsite soil or ground water. Of the metals detected in both onsite and offshore areas, some risk was associated with arsenic in offshore shellfish as well as onsite ground water. Arsenic was detected in several shallow ground-water monitoring wells in the southern portion of the site. The maximum concentration of arsenic in shallow ground water near the shoreline (46.9 μg/L) was detected in a sample from MW07-26S (from the Phase I, II, and III RI, only one ground-water sample had a higher concentration of arsenic but this was located in the central portion of Site 07 - MW07-09D: 63.5 μg/L). Closer to the shoreline, arsenic concentrations decreased in MW07-19S (3.8 J μg/L) and MW07-13S (8 J μg/L); however, at the shoreline in MW07-21S, arsenic was non-detect. Therefore, because the elevated concentrations observed at MW07-26S do not appear to extend beyond the shoreline, arsenic concentrations detected in sediment may not have originated from shallow ground water at Site 07. Similarly, in deep and bedrock ground water at Site 07, arsenic was non-detect along the southern shoreline.

1.4.6 Transport and Fate

1.4.6.1 VOC in Ground Water

As described in Section 1.4.2, transport of VOC at Site 07 appears to be primarily controlled by the geology of the site. In shallow ground water (Figure 1-19), there appears to be two dissolved-phase VOC plumes; the first plume of relatively low concentrations of total chlorinated-VOC is located in the vicinity of the former DANC disposal area and the second plume (with higher total chlorinated-VOC concentrations) is located in the southwest portion of the site (MW07-19S, -21S, and -26S) where there are no reported disposal activities. The second shallow plume may be an extension of the plume in deep ground water due to the impact on ground-water flow from a salt water "wedge" located south of the site.

Based upon the Phase III RI, it appears that 1,1,2,2-PCA (a major component of DANC) from the former DANC disposal area migrated vertically downward through a locally present sandy facies of the underlying silt unit (fresh ground-water zone) into the underlying till unit and fractures of the bedrock unit (brackish and saline ground-water zones) rather than laterally through the upper sand unit. The apparent valley in the bedrock topography in the vicinity of the DANC disposal area (Figure 1-15) appears to have partially influenced the migration and collection of the original DANC disposal release of separate-phase (free-flowing) 1,1,2,2-PCA

DNAPL. Although no free-flowing DNAPL has been measured in the Site 07 wells during the Phase I, II, or III RI, the observed concentrations of TCE and 1,1,2,2-PCA (i.e., effective pore water concentration greater than 1% of the solubility for those compounds) suggest that there may be residual DNAPL (of TCE and/or 1,1,2,2-PCA) in the vicinity of MW07-04D, MW07-05D, MW07-15D, and MW07-17D. If present, the original free-flowing DNAPL appears to have migrated vertically downward from the DANC disposal area, through a sandy facies in the overlying silt unit into the till unit, migrated along a portion of the apparent valley in the bedrock surface, and down into fractures in bedrock. Dissolved chlorinated-VOC detected in ground water from bedrock wells probably is migrating through fractures in the bedrock and through the overlying till unit which appears to be in direct hydraulic connection with the bedrock (Figures 1-20 and 1-21). In bedrock, ground-water flow is limited to fractures, joints, and bedding planes. Some of the bedrock fractures may not be locally oriented in the same direction as the overall flow of shallow, deep, and bedrock ground water to the southeast. This is believed to be a key reason for the southerly extension of the dissolved-phase VOC plume at Site 07.

1.4.6.2 Potential Impact on Adjacent Surface Water Bodies by Migration of Solutes in Ground Water from Site 07

As modeled during the Phase III RI, the estimated VOC and metals surface water concentrations for the Allen Harbor entrance channel resulting from the migration of ground water from the site were well below Ambient Water Quality Criteria (AWQC). However, due to the complex hydrogeology of the site and the limitations of the model used, the model can not accurately predict COC concentrations in ground water exiting the site. Therefore, additional monitoring will be required at discharge areas to ensure that the site continues to pose no unacceptable risks to adjacent surface water bodies. To date, no adverse impacts from Site 07 to adjacent surface water bodies have been identified. Due to the overlying silt layer, upward moving deep ground water would be susceptible to increased plume attenuation resulting from dilution, the increased retardation factors (e.g., the lower permeability and higher absorption capacity of silt), and biodegradation. In the area where an overlying silt layer is not present (at MW07-21), the total VOC concentration in deep ground water is less than that for shallow ground water which was modeled to show no adverse impacts. Similarly, bedrock ground water can only reach the surface water of the Allen Harbor entrance channel by moving up through the till unit and possibly the lower sand and silt units, where present.

1.4.6.3 Potential Impact of Solutes in Ground Water from Site 07 on Adjacent Intertidal Sediment

During the Phase III RI, analysis of Site 07 ground-water data using conservative sediment partitioning theory and relatively simplistic ground-water modeling provided a rough estimate of the potential movement of the TCL-VOC and TAL-metals detected in ground-water samples. Here, only iron, manganese, TCE, and 1,2-DCE were estimated to potentially result in sediment concentrations above sediment screening criteria (at 5% TOC) at the Allen Harbor entrance channel shoreline in either the shallow or deep/rock ground-water zones. Iron was not identified as a sediment COC in the Marine or Freshwater/Terrestrial ERA. Manganese was only identified as a sediment COC in the Freshwater/Terrestrial ERA. In the shallow zone, 1,2-DCE is below sediment screening criteria at a 1% TOC and is slightly below the AWQC when the near shore concentration at MW07-21S is modeled to the shoreline. VOC (i.e., TCE and 1,2-DCE) were not identified as sediment COC in either the Marine or Freshwater/Terrestrial ERA.

However, due to the complex hydrogeology of the site and the limitations of the model used, the model can not accurately predict COC concentrations in ground water exiting the site. Therefore, additional monitoring will be required at discharge areas to ensure that the site continues to pose no unacceptable risks to adjacent surface water bodies. To date, no adverse impacts from Site 07 to adjacent surface water bodies have been identified. Potential impacts to the adjacent intertidal sediment from the deep/rock wells are expected to be less than those estimated for shallow ground water because deep/rock ground water would have to pass through shallow ground water prior to discharging (see Section 1.4.6.2).

1.4.7 Human Health Risk Assessment

The Site 07 HHRA characterized risks associated with chemicals detected in the following onsite and offshore media associated with Calf Pasture Point: surface soil, subsurface soil, ground water, surface water, sediment, shellfish tissue, and soil gas. All available data (i.e., from the Phase I, II, and III RI reports) were used during the HHRA. The Base Reuse Plan for Calf Pasture Point specifies open space/conservation which may include recreational activities. Thus, the exposure scenarios evaluated were (1) future construction/remediation workers, (2) future recreational users, (3) consumers of locally caught, non-depurated shellfish, and (4) hypothetical future residents. The future recreational scenario included the assumption that a showering facility could be constructed which utilizes ground water from the site.

1.4.7.1 Summary of Cancer Risk Estimates

The results for cancer risk analysis during the Phase III RI showed that the following exposure pathways that may be of concern at, or adjacent to, Site 07:

- ingestion of deep and bedrock ground water by residential populations under average and Reasonable Maximum Exposure (RME) exposure scenarios (VOC under both scenarios and arsenic and beryllium only under a RME scenario);
- inhalation of VOC from deep and bedrock ground water by recreational populations while showering under average and RME exposure scenarios;
- dermal contact with VOC in deep and bedrock ground water by recreational populations while showering under RME scenario;
- ingestion of shoreline shellfish under RME scenario.

The other pathways studied during the Phase III RI resulted in cancer risks less than one-in-ten thousand (10^{-4}), indicating that the cancer risks fall in the acceptable range according to EPA policy. The elevated risk to human health from eating shellfish is not directly related to Site 07 nor the Site 07 COC. For the consumption of shellfish, the major contributors to the total estimated cancer risk were from arsenic, polycyclic aromatic hydrocarbons (PAH), and PCB. No PCB have been detected at Site 07.

The use of deep and bedrock ground water for residential drinking and recreational showering are scenarios requested by EPA, but are not required for the planned use of the site as a recreational-use or conservation area. Although Calf Pasture Point may be developed for recreational use in the future, it is unlikely that ground water at Site 07 would be used as a drinking water source because (1) the aquifer at Site 07 has limited value as a potential drinking water source due to the high salinity identified beneath much of the site and (2) public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) the impacted portion of the aquifer at Calf Pasture Point was found to be low-yielding during the Navy's ground-water investigations. It should also be noted that the unacceptable exposure scenarios related to ground water are from the VOC plume area and not the entire site[1].

Cancer risks greater than one-in-one million (10^{-6}) at or adjacent to Site 07 were associated with:

- Ingestion of deep and bedrock ground water for exposed residential populations. Major contributors to the total estimated risks were from arsenic, beryllium, and VOC, including benzene, chloroform, 1,2-dichloroethane (1,2-DCA), 1,1-dichloroethene (1,1-DCE), PCE, 1,1,2,2-PCA, 1,1,2-TCA, TCE, and VC.

- Dermal contact with and inhalation of VOC from deep ground water for exposed recreational populations while showering under average exposure conditions. Major contributors to the total estimated risks were from 1,1,2,2-PCA, TCE, VC, 1,1,2-TCA, 1,2-DCA, 1,1-DCE, chloroform, and benzene.

- Dermal contact with and inhalation of VOC from bedrock ground water for exposed recreational populations while showering. Major contributors to the total estimated risks were 1,1,2,2-PCA, TCE, VC, 1,1,2-TCA, 1,1-DCE, and chloroform.

- Ingestion of arsenic in offshore sediment was associated with cancer risks greater than 10^{-6} but less than 10^{-4} (i.e., within the range of acceptable risk) for some exposed recreational populations under RME conditions. Arsenic is not a COC at

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[1] Human health risk was estimated based upon maximum COC concentrations; however, the ground-water plume does not affect all portions of Site 07 (Figures 1-19 to 1-21). The redevelopment of Calf Pasture Point (e.g., location of public beaches and/or trails) is not precisely known at this time; however, sandy beaches are generally located along the eastern shore (Narragansett Bay) which is beyond the extent of the plume. Existing paved, access roads are located to the north of Site 07 (upgradient) and are also beyond the extent of the plume.

Site 07 and elevated levels of arsenic were not detected in Site 07 soil or ground water during the Phase III RI.

- Major contributors for risks from the ingestion of shoreline shellfish included arsenic, benzo(a)pyrene, benzofluoranthene, dibenzo(a,h)anthracene, and PCB. Arsenic, PAH, and PCB were not identified as COC at Site 07. The presence of these compounds in shoreline shellfish has not been linked to Site 07.

- For entrance channel recreational exposure scenarios, dermal contact with surface water for adult receptors under average exposure scenario and incidental ingestion of and dermal contact with surface water for adults and children under RME conditions were associated with cancer risks greater than 10^{-6} but less than 10^{-4} (i.e., within the range of acceptable risk).

1.4.7.2 Summary of Risks for Health Effects Other than Cancer

The results for the non-cancer risk analysis performed in the Phase III RI showed the following exposure pathways that may be of concern at or adjacent to Site 07:

- ingestion of deep and bedrock ground water by residential populations under average and RME exposure scenarios (VOC under both scenarios; manganese and chromium under average exposure; and manganese, arsenic, aluminum, and thallium under a RME scenario);
- inhalation of VOC from deep and bedrock ground water by recreational populations while showering under average and RME exposure scenarios;
- dermal contact with VOC in deep and bedrock ground water by recreational populations while showering under RME scenarios; and
- ingestion of shoreline shellfish (offsite media) under average and RME scenarios.

The other pathways studied resulted in non-cancer hazard indices (HI) less than unity (1), indicating that the non-cancer risks fall in the acceptable range according to EPA policy. The elevated risk to human health from eating shellfish is not directly related to Site 07 nor specifically to VOC (the constituents at Site 07).

It should be noted that the unacceptable exposure scenarios related to ground water were determined using data from the VOC plume area and not the entire site. Although Calf Pasture Point may become a recreational-use area, it is unlikely that ground water at Site 07 would be used as a drinking water source because (1) the aquifer at Site 07 has limited value as a potential drinking water source due to the high salinity identified beneath much of the site, (2) public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) the impacted portion of the aquifer at Calf Pasture Point was found to be low-yielding during the Navy's ground-water investigations.

HI greater than 1 identified at or adjacent to Site 07 were associated with:

- Consumption of deep and bedrock ground water containing manganese, arsenic, aluminum, thallium, chromium, chloroform, 1,1-DCE, 1,2-DCE, PCE, 1,1,2-TCA, and TCE was associated with estimated hazard quotients greater than 1.0 for some exposed residential populations under average and/or RME exposure conditions. Evaluation of separate target organ HIs indicated that exposures to these COC may result in adverse health effects in the liver, skin, gastrointestinal tract, central nervous system, lungs, and kidneys.

- Dermal contact with and inhalation of VOC from deep ground water while showering were associated with estimated hazard quotients for exposed recreational populations that are greater than 1.0 under average (inhalation only) and RME conditions. Evaluation of separate target organ HIs indicates that exposure to TCE, 1,1-DCE, PCE, chloroform, 1,2-DCE, and 1,1,2-TCA may be associated with adverse health effects in the liver and kidneys.

- Concentrations of mercury, zinc, arsenic, copper, cadmium, and PCB in shoreline shellfish were associated with estimated hazard quotients for certain exposed groups that are greater than 1.0. Evaluation of separate target organ HIs indicates that exposures to these constituents may result in adverse health effects in the kidneys, skin, gastrointestinal tract, blood, and liver. The presence of metals in shoreline shellfish has not been linked to Site 07. No PCB have been detected at Site 07.

2. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

2.1 INTRODUCTION AND DESCRIPTION OF EVALUATION PROCESS

The primary objective of this phase of the FS is to identify and develop appropriate waste management options that will be evaluated more completely in the Detailed Analysis phase contained in Chapters 4 and 5. SARA requires the EPA to select a remedy that utilizes permanent solutions, alternative treatment technologies, or resource recovery techniques to the maximum extent practicable.

Pursuant to CERCLA/SARA guidance, the major steps of the multi-phased approach to the FS process are to:

1. Establish Remedial Action Objectives
2. Develop General Response Actions
3. Identify Potential Treatment and Disposal Technologies
4. Screen Technologies
5. Develop Remedial Action Alternatives
6. Analyze Remedial Action Alternatives
7. Summarize and Compare Remedial Action Alternatives

This chapter describes the step-by-step process for identifying and screening potential technologies. A review of applicable or relevant and appropriate federal and state environmental and public health requirements for remedial actions is presented in Section 2.2. Media and receptors of concern are identified in Section 2.3 with respect to the media being considered for remedial actions. Preliminary Remediation Goals (PRG) are discussed in Section 2.4. Remedial Action Objectives (RAO) and General Response Actions are outlined in Sections 2.5 and 2.6, respectively. Section 2.7 addresses the identification and screening of remedial technologies. In some cases, process options, rather than individual remedial technologies, are evaluated to simplify the screening process. Process options are relatively similar or equivalent technologies which will achieve the same or a similar end result, or are closely related to one another. When a group of technologies is evaluated as a process option, this implies that the use of any of the technologies would be similar. This simplifies the technology screening process. The initial screening will be completed to identify technically feasible technologies for development into remedial alternatives. The development, detailed analysis, and summary of remedial action alternatives are included in Chapters 3, 4, and 5, respectively. The detailed analysis and summary of remedial action technologies will be used in development of the Proposed Remedial Action Plan (PRAP) and final Record of Decision (ROD) for Site 07.

2.2 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Pursuant to SARA and the NCP, the development and evaluation of remedial actions under CERCLA must include a comparison of alternative site remedies to Applicable or Relevant and

Appropriate Requirements (ARARs). In recognition of the unique characteristics and circumstances associated with remediation of individual sites, neither SARA nor the NCP provide specific standards for the determination of whether a particular remedy provides sufficient cleanup at a given site. It is essential that any remedial action selected meet all ARARs unless specific waivers have been granted.

2.2.1 Definition of ARARs

A requirement under CERCLA/SARA, as amended, may be either "applicable" or "relevant and appropriate" to a site-specific remedial action, but not both.

- **Applicable Requirements**—These cleanup standards are standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances at a CERCLA site.

- **Relevant and Appropriate Requirements**—These cleanup standards are standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well suited to the particular site. In some circumstances, a requirement may be relevant, but not appropriate, for the site-specific situation.

2.2.2 Identification of ARARs

ARARs for remedial action alternatives at Site 07 can be generally classified into one of the following three functional groups:

- Chemical-specific: Health- or risk-based numerical values or methodologies that establish cleanup levels or discharge limits for particular contaminants.

- Location-specific: Requirements that restrict remedial actions based on the characteristics of the site or its immediate environs. Typical examples of location-specific ARARs include the State of Rhode Island Coastal Resources Management Program (CRMP) guidelines and federal/state wetlands protection guidelines.

- Action-specific: Requirements that set controls or restrictions on the design, implementation, and performance levels of activities related to the management of hazardous substances, pollutants, or contaminants. Typical examples of action-specific ARARs include Rhode Island Hazardous Waste Management regulations and CWA National Pollutant Discharge Elimination System (NPDES) requirements.

To be consistent with the NCP definition of ARARs and changes made by SARA, the following groups of ARARs were considered during the identification process:

- Federal requirements (applicable, relevant and appropriate);
- State of Rhode Island requirements (applicable, relevant and appropriate);
- Federal criteria, advisories, and guidance documents; and
- State of Rhode Island criteria, advisories, and guidance documents.

As a risk-management site, no chemical-specific ARARs were identified for Site 07. Summaries of the location-specific and action-specific ARARs, which address each of the remedial alternatives developed for Site 07, are presented in Chapter 3.

2.2.3 To-Be-Considered Guidance

Federal and state guidance documents or criteria that are not generally enforceable, but are advisory, do not have the status of potential ARARs. Guidance documents or advisories "To Be Considered" (TBC) in determining the necessary level of cleanup for protection of human health or the environment may be used where no specific ARARs exist for a chemical or situation, or where such ARARs are not sufficient to afford protection. No chemical-specific or location-specific TBCs were identified for Site 07. Summaries of the action-specific TBCs which address each of the remedial alternatives developed for Site 07, are presented in Chapter 3.

2.2.4 Circumstances in Which ARARs May Be Waived

Pursuant to Section 300.430(f)(3) of CERCLA, several criteria presently exist pursuant to which all ARARs need not be attained. These waivers apply only to meeting ARARs with respect to onsite remedial activities. A waiver must be invoked for each ARAR that will not be attained or exceeded. Other statutory requirements, such as those requiring that remedies must be cost-effective, cannot be waived.

Six criteria for waivers of ARARs are provided for by CERCLA Section 121(d)(4). One of the six is applicable to Superfund-lead projects only, and is not applicable to this project. The other five criteria are as follows:

1. The remedial action selected is only part of a total remedial action that will attain such level or standard of control when completed.

2. Compliance with such requirements at the facility will result in greater risk to human health and the environment than alternate options.

3. Compliance with such requirements is technically impracticable.

4. The remedial action selected will attain a standard of performance that is equivalent to that required under the otherwise applicable standard, requirement, criteria, or limitation, through use of another method or approach.

5. With respect to a state standard, requirement, criteria, or limitation, the state has not consistently applied (or showed the intention to consistently apply) the standard, requirement, criteria, or limitation in similar circumstances at other remedial actions.

2.3 IDENTIFICATION OF MEDIA/POTENTIAL RECEPTORS OF CONCERN

This FS develops and evaluates remedial alternatives for addressing RAO for Site 07 environmental media (soil and ground water). Remedial alternatives for Site 07, which are developed in Chapter 3 and analyzed in detail in Chapters 4 and 5, will consist of potential whole-site solutions. Remedial alternatives developed for Site 07 primarily will address risks to human health because no significant ecological risks were identified for Site 07. The results of the Facility-Wide Freshwater/Terrestrial ERA indicated that there is no significant terrestrial ecological risk from Site 07 surface soil. The results of the Allen Harbor Landfill and Calf Pasture Point Marine ERA indicate that, regarding potential risk to the marine ecology, a cause-and-effect relationship could not be established for Site 07.

2.3.1 Site 07 Environmental Media

The following onsite environmental media were considered:

- Surface Soil: Includes soil located from 0 to 2 ft below the site surface.

- Subsurface Source Area: Includes soil located at depths greater than 2 ft below the site surface to the top of bedrock.

- Ground Water: Includes ground water located within the shallow, deep, and bedrock zones below the site. The shallow ground-water zone, which is under unconfined conditions, is the saturated portion of the upper sand and (in the southern portion of the site) the upper till unit. The deep ground-water zone is the lower portion of the silt unit, the lower sand unit (where present), and the till unit which respond like a confined aquifer. The bedrock ground-water zone is the upper 25 to 30 ft of competent (solid) bedrock which responds like a confined aquifer. During the Phase III RI, it was observed that the majority of the bedrock cores showed multiple fractures. Ground-water flow through bedrock at the site is likely controlled by the presence of these fractures. The Navy conducted a seismic refraction survey during the Phase II RI; however, the extent and thickness of the highly fractured or highly weathered bedrock could not be assessed.

Excess cancer risks [greater than one-in-one million ($>10^{-6}$)] to human health from chemical concentrations in ground water were associated with the hypothetical exposures resulting from the ingestion of deep and bedrock ground water by potential residential populations (due to concentrations of arsenic, beryllium, and VOC, including benzene, chloroform, 1,2-DCA, 1,1-DCE, 1,1,2,2-PCA, 1,1,2-TCA, TCE, and VC) and the inhalation/dermal contact by recreational populations with deep and bedrock ground water while showering (primarily from concentrations of 1,1,2,2-PCA, TCE, VC, 1,1,2-TCA, 1,2-DCA, 1,1-DCE, chloroform, and benzene).

Excess non-cancer risks (HQ > 1) to human health were associated with the consumption of deep and bedrock ground water by residential populations (due to concentrations of arsenic, manganese, chromium, aluminum, thallium, chloroform, 1,1-DCE, 1,2-DCE, 1,1,2-TCA, and TCE) as well as dermal contact with and inhalation of VOC from deep and bedrock ground water while showering by recreational populations (due to concentrations of TCE, 1,1-DCE, PCE, chloroform, 1,2-DCE, and 1,1,2-TCA).

The exposure is related to ground water from the VOC plume area and not the entire site. Although Calf Pasture Point may become a conservation or recreational-use area, ground water at Site 07 would not likely to become a source for potable water in the future. The aquifer at Site 07 has limited value as a potential drinking water source due to the high salinity identified beneath much of the site. Furthermore, public water service is currently available to the adjacent community to the north of Calf Pasture Point and the impacted portion of the aquifer at Calf Pasture Point was found to be low-yielding during the Navy's ground-water investigations.

2.3.2 Offshore Environmental Media

Shoreline sediment (intertidal and subtidal sediment adjacent to Site 07) has the potential to contact impacted ground water from Site 07. During the HHRA, cancer risks (risk $> 10^{-6}$) to human health were identified for the incidental ingestion of sediment by recreational users due to the concentrations of arsenic under RME conditions. However, the risk was within the acceptable risk range (i.e., less than 10^{-4}) and elevated levels of arsenic were not identified in ground water which may contact shoreline sediment.

2.3.3 Potential Offshore Ecological Receptors of Concern

Potential offshore ecological receptors, with respect to the migration of Site 07 ground water, include shellfish resources along the shoreline of Site 07. The Marine ERA categorized risks to shellfish along the shoreline of Site 07 as low to moderate (furthermore, these risks were not linked to VOC which are the COC at Site 07). During the HHRA, cancer risks (risk $> 10^{-6}$) to human health were identified with the ingestion of shellfish [due to concentrations of arsenic, benzo(a)anthracene, benzo(a)pyrene, benzofluoranthene, dibenzo(a,h)anthracene, and PCB]. Non-cancer risks (HQ > 1) to human health were associated with concentrations of mercury, zinc, arsenic, copper, cadmium, and PCB in shellfish. However, the elevated cancer and non-cancer risks to human health from eating shellfish are not directly related to Site 07 nor specifically to VOC (the constituents at Site 07).

2.4 PRELIMINARY REMEDIATION GOALS

Preliminary Remediation Goals (PRG) for Site 07 were developed using federal and state ARARs as well as NCBC Davisville background concentrations. Federal and state ground-water criteria were identified as action-specific performance standards (Tables 3-5, 3-7, 3-9, and 3-11) that will be used to evaluate the effectiveness for remedial alternatives to address COC concentrations. The performance standards would also be used to evaluate the remedial alternatives' protectiveness of human health and the environment. RIDEM's remediation criteria are contained in the Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases (short title: "Remediation Regulations"; DEM-DSR-01-93, as amended August 1996). The Remediation Regulations provide standards and Upper Concentration Limits (UCL) for soil [based on direct contact (residential and commercial/industrial) and leachability (for Class GA and GB ground-water regions)] and ground water (Class GA and GB regions).

The Remediation Regulations provide three methods for determining remediation criteria. Method 1 allows for the use of promulgated soil and ground-water objectives. Method 1 objectives are contained in the Remediation Regulations in tabular form. Method 2 allows for the consideration of limited site-specific information to modify some Method 1 objectives or to calculate objectives for substances not promulgated under Method 1. Method 2 objectives may be used alone or in conjunction with Method 1 objectives. Procedures for calculating Method 2 objectives are contained in the Remediation Regulations. Method 3 allows for a site-specific risk assessment to be conducted by the performing party. Method 3 can not be combined with Method 1 or 2. A site-specific human health risk assessment under Method 3 may be conducted only after review and approval of a Human Health Risk Assessment Work Plan by RIDEM. UCLs in soil and ground water are "...concentrations of a hazardous substance which, if exceeded, may pose a significant potential for causing a nuisance condition and may demarcate a transition between contaminated environmental media and waste in the environment." If any Method 2 or 3 remedial objective results in a value exceeding an UCL, then the Method 2 or 3 objective must be adjusted downward to a concentration which prevents this. In addition to Method 1, 2, and 3 remedial objectives for soil and ground water, the Rhode Island Remediation Regulations also allow for the use of background concentrations for establishing remedial objectives.

2.4.1 Development of PRG for Environmental Media at Site 07

For developing Site 07 PRG, soil and ground-water data obtained from the Phase I, II, and III RI were compared to RIDEM's Method 1 standards. Data exceeding these standards were then compared to background concentrations for Site 07. In developing PRG for Site 07, the results of the HHRA were considered with respect to which constituents were considered to be COC for the site. PRG for the various environmental media of concern at Site 07 were developed as follows:

Surface Soil

RIDEM's Remediation Regulations specify that soil shall be remediated to satisfy both direct exposure and leachability criteria or to background levels for the site. For the direct exposure criteria in surface soil, the regulations specify that residential criteria will be used for the vadose zone. Site 07 is located within a Class GB ground-water region; therefore, GB leachability criteria were employed. Background levels for surface soil were developed during the Phase II RI (TRC 1994).

Subsurface Soil

RIDEM's Remediation Regulations specify that commercial/industrial direct soil exposure criteria can be used for subsurface soil provided that current or future use is not anticipated to result in exposure to soil beyond a depth of 2 ft bgs. Site 07 is located within a Class GB ground-water region; therefore, GB leachability criteria were employed. In lieu of any available subsurface soil background concentrations, NCBC Davisville surface soil background concentrations were considered.

Shallow, Deep, and Bedrock Ground Water

RIDEM has classified ground water at Site 07 as GB (not suitable for public or private drinking water use without treatment). As per RIDEM's Remediation Regulations, "...GB ground water shall be remediated to a concentration which meets the ground-water objective...or the background concentration of the hazardous substance." Background concentrations of inorganic compounds were obtained from the Basewide Ground-Water Inorganics Study Report (Stone & Webster 1996). Federal AWQC, MCL, and SMCL were also identified as relevant and appropriate ARARs for ground water; however, these criteria are reserved for the treatment and/or discharge of ground water (for potential remedial alternatives which specify ground-water extraction). Therefore, Method 1 Class GB ground-water objectives and NCBC Davisville background levels were used in the development of ground-water PRG.

2.4.2 Screening Values for Potential Offshore Environmental Media and Ecological Receptors

Offshore Environmental Media

Chemical constituents identified in shoreline sediment were not linked to Site 07; therefore, no PRG have been established for sediment in this FS.

Potential Offshore Receptors of Concern

The chemical constituents identified in shellfish were not linked to Site 07; therefore, no PRG have been established for shellfish in this FS.

2.4.3 Comparisons to PRG

Onsite environmental data were compared to PRG, as described in Section 2.4.1 (Tables 2-1 through 2-4).

Surface Soil: Surface soil data meet the PRG. As shown in Table 2-1, only arsenic (1.5 mg/kg) exceeded any of the PRG for surface soil. However, as shown in Table 2-3, this concentration was within NCBC Davisville background levels. Compounds which did not have PRG were not identified as COC in the HHRA.

Subsurface Soil: Subsurface soil data meet the PRG (Table 2-2). As shown in Table 2-3, various inorganic constituents exceeded NCBC Davisville surface soil background levels; however, these constituents were not identified as COC in the HHRA.

Ground Water: As shown in Table 2-4, various organic constituents of shallow, deep, and bedrock ground water exceeded RIDEM's Class GB criteria. This includes the following constituents:

shallow:	TCE
deep:	benzene, 1,2-DCA, 1,1-DCE, 1,2-DCE (total), PCE, and TCE
bedrock:	1,1-DCE and TCE

2.5 REMEDIAL ACTION OBJECTIVES

Generalized, conceptual-level Remedial Action Objectives (RAO) were developed for the environmental media at Site 07 based upon the results of the RI, HHRA, ERA, and the Site 07 PRG (performance standards). These RAO are used in Chapter 3 to develop remedial action alternatives which protect human health and the environment.

No RAO were identified for surface soil or subsurface soil because no onsite terrestrial ecological or human health risks were identified and PRG or background levels were not exceeded. No RAO were identified for offshore environmental media (e.g., shoreline sediment or shellfish) because (1) although there is a ground-water pathway from the site to offshore areas, no unacceptable human health risks have been identified from ground-water migration, (2) the Marine ERA indicated that a cause-and-effect relationship could not be established for potential risks to the marine ecology from Site 07, and (3) the low ecological risks identified along the shoreline have not been linked to Site 07 (i.e., these low risks are attributable to non-site related COC).

RAO for ground water were developed to address the unacceptable risks identified during the HHRA as well as the constituent concentrations that exceeded PRG (Section 2.4). As outlined in Section 2.3, the following possible pathways for site risks to human health were identified in the HHRA:

Cancer pathways
- ingestion of deep and bedrock ground water by residential populations;
- inhalation of VOC from, and dermal contact with, deep and bedrock ground water while showering by recreational users;

Non-cancer pathways
- ingestion of deep and bedrock ground water by residential populations;
- inhalation of VOC from, and dermal contact with, deep and bedrock ground water while showering by recreational users.

RAO for Site 07 are presented in Table 2-8. Due to the low risks at the site and the likely technical impracticability for treating COC in fractured bedrock, the RAO for Site 07 focus on protecting human health and the environment through preventing exposure.

2.6 GENERAL RESPONSE ACTIONS

General Response Actions describe those actions which will satisfy the RAO. General Response Actions typically can include treatments, extraction, institutional controls, etc., or combinations of these options.

As outlined above, potential risks to human health under the hypothetical exposure scenarios relate to the use of deep and bedrock ground water. As described in Section 2.4, some PRG were exceeded in shallow, deep, and bedrock ground water. RAO for each media/receptor of concern were developed to prevent human exposure to impacted ground water (Table 2-8). Also in Table 2-8, overall General Response Actions were developed for each of the RAO in order to serve as a guide for the development of potential remedial alternatives.

Based upon the information in Table 2-8 and the RI, whole-site General Response Actions have been developed to identify the spectrum of technologies that have demonstrated promise in remediation of environmental conditions similar to those identified at Site 07 (Table 2-9). Evolving technologies, such as those being demonstrated under EPA's Superfund Innovative Technology Evaluation (SITE) program were examined in addition to traditionally accepted remedial action technologies. The identified response actions and technologies include no action, institutional controls, ground-water treatment, and ground-water containment. As required by EPA, the "No Action" alternative was used as a baseline for evaluation of the comparative advantages and disadvantages of other alternatives. This FS focuses on evaluating the effectiveness of remedial alternatives in abating risks to human health and the environment from established exposure pathways, thereby providing a basis for follow-on decision making on remedial actions.

Remedial alternatives for Site 07 will address COC concentrations in shallow, deep, and bedrock ground water. Hypothetical future use of ground water (drinking water or shower water) has been identified as the primary risk pathway of concern [however, this is an unlikely exposure pathway because (1) the high salinity of ground water at Site 07 limits its use as a viable drinking water aquifer, (2) public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) the impacted portion of the aquifer at Calf Pasture Point was found to be low-yielding during the Navy's ground-water investigations]. Soil constituent concentrations were determined not to pose a risk to human health or the environment (or were within background levels) and a source area associated with soil has not been identified; therefore, no remedial goals have been identified for surface or subsurface soil.

2.7 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

2.7.1 Screening Process

The first step in a technology screening for site remediation is to examine a variety of available remedial technologies and to identify those technologies that warrant further consideration based on the applicability of the technology for the site-specific conditions and COC. The primary focus of this evaluation is the effectiveness and implementability of each option, with less emphasis on cost, as follows.

Effectiveness - The effectiveness evaluation is focused on the following elements:

- The potential effectiveness of process options in handling the estimated areas or volumes of media and in meeting the remediation goals identified in the RAO;
- The potential impacts to human health and the environment during the construction and implementation phase; and
- The reliability and proven effectiveness of the process with respect to the COC and the site-specific conditions.

Implementability - The implementability evaluation includes both the technical and institutional feasibility of implementing each technology or process. This initial technology screening eliminates technology types or process options that are clearly ineffective or unworkable at the site. These institutional aspects include:

- The potential for obtaining regulatory approval;
- The availability of necessary equipment and skilled workers to implement the technology;
- The availability of treatment, storage, and disposal services; and

- The time required for implementation.

Cost - The screening of alternatives is intended to evaluate the technical feasibility and implementability of remedial technologies in addressing the RAO under site-specific operating conditions. For this screening evaluation, a qualitative cost analysis has been presented only if costs were uncommonly prohibitive and if other process options within the same technology type were comparably effective and implementable. Preliminary cost estimates for the remedial technologies are presented in Chapters 3 and 4 as part of each of the remedial alternatives developed from the technologies retained in this chapter.

The preliminary technology screening is presented in the following sections. Table 2-10 summarizes the first-stage screening results. The second stage of the screening (presented in Chapter 3) is an examination of potential remedial alternatives developed using technologies retained from the preliminary technology screening.

2.7.2 Institutional Controls

Several institutional controls, which can be used to address site risks alone in or conjunction with other remedial actions, are presented in Sections 2.7.2.1 through 2.7.2.4.

2.7.2.1 Monitoring

Monitoring involves the collection of environmental samples to evaluate temporal trends in the quality of environmental media and receptors. At Site 07, monitoring could include collection and analysis of shallow, deep, and bedrock ground-water samples (to evaluate trends or stability of COC concentrations onsite), as well as monitoring of potential offshore media such as shoreline sediment and shellfish. Ground-water monitoring is usually accomplished using ground-water wells and piezometers through which samples can be collected and/or ground-water quality measurements made. Should a remedial action include ground-water extraction with onsite treatment and discharge, monitoring of discharge from the treatment system would be performed, as required by the federal and state pollutant discharge standards. Monitoring regimens can include continuous, daily, weekly, monthly, quarterly, semi-annual, annual, or less frequent monitoring.

- **Effectiveness** - In general, monitoring can be an effective technique to evaluate the long-term trends of site COC and/or treatment technology performances. In the absence of uncontrolled risks at a site, if it is determined during the 5-year reviews that the ground-water plume is not generating new risks (e.g., either through expansion or increased COC concentrations), then it may be acceptable to reduce the frequency of monitoring or to eliminate further monitoring until there are new site uses that would warrant re-evaluation of COC levels in ground water.

- **Implementability** - Monitoring would be readily implementable at Site 07 because the existing monitoring well network could be used or modified.

Environmental monitoring is a standard and effective means for evaluating the effectiveness of implemented remedial actions. Therefore, monitoring will be retained for further consideration.

2.7.2.2 Point-of-Entry/Use Treatment

Point-of-entry/use treatment technologies, typically consisting of carbon filters or ion exchange units, can be used by residences that are dependent on ground water for their drinking water. Carbon filters are used to remove organic compounds from water. Ion exchange units typically are used to reduce metal concentrations in water by using a resin bed to exchange a non-harmful metal, like sodium, for the target metal. Point-of-entry treatment is accomplished prior to tap use. The treatment units are usually located in the basement of the residence and the treated water is used by the residents for domestic water uses (e.g., drinking, bathing, washing clothes).

Point-of-entry/use treatment techniques can be effective in reducing human exposure to ground-water COC. However, there currently are no residences that use ground water affected by Site 07. Although Calf Pasture Point may become a conservation or recreational-use area, it is also unlikely that ground water at Site 07 would be used as a drinking water source in the future because (1) the aquifer at Site 07 has limited value as a potential drinking water source due to the high salinity identified beneath much of the site, (2) public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) the impacted portion of the aquifer at Calf Pasture Point was found to be low-yielding during the Navy's ground-water investigations. Therefore, point-of-entry/use treatment technologies will not be retained for further consideration.

2.7.2.3 Site Use Restriction/Limitations

Site use restrictions include property access controls, restrictions, and limitations on future site development. Control of site access can be accomplished through installation of fencing. A chain-link fence, with a locked gate, currently restricts unauthorized personnel from entering using Sanford Road. Small boats can access the site via Allen Harbor and Narragansett Bay. The existing fencing is a general area fence and limits public access to other areas adjacent to Site 07, as well as Sanford Road. Should the public be allowed access to adjacent areas and/or use of Sanford Road in the vicinity of Calf Pasture Point in the future, the current fencing will not restrict public access to Site 07. Fencing can be an effective means of controlling site access; however, no risks have been associated with the surface conditions at Site 07. Therefore, fencing would not be required and it will not be retained for further consideration.

Deed or land-use restrictions can be used to control construction and/or ground-water usage at the site. This can include zoning limitations, physical limitations on the size and weight of improvements, and installation prohibitions (e.g., preventing excavation or well installations).

Calf Pasture Point will be transferred to the Town of North Kingstown as a public benefit conveyance for use as an open space/conservation area. Acquisition in this manner restricts the transferee to use the property for the purpose of a park and recreation in perpetuity with no opportunity for resale or commercial development. The responsibility to abide by any deed restriction on the use of site property will be that of the Town of North Kingstown in perpetuity.

Institutional controls such as land use restrictions can be effective and implementable techniques to control public exposure to site hazards; therefore, land use restrictions (which may include deed restrictions for ground-water use) will be retained for further consideration.

2.7.2.4 Alternate Water Supply

Alternate water supplies, generally bottled water or municipal (i.e., piped) water, can be implemented at a site as a means of protecting the health of local residents that may be dependent on ground water for their drinking water. Providing an alternate water supply can be effective in reducing human exposure to ground-water contaminants for residences depending on ground water for domestic use. However, as discussed for point-of-entry treatment techniques, there currently are no residences that use ground water affected by Site 07 and public water is already available to the adjacent community to the north of Calf Pasture Point. Therefore, use of alternate water supplies will not be retained for further consideration.

2.7.3 Source Control/Treatment Technologies

Source control technologies can be used to isolate waste material and affected soil. Source control technologies can include capping or containment walls. Source treatment technologies can be used to treat waste material and affected soil in order to remove or reduce a source of contamination. Source treatment technologies include *ex-situ* techniques such as excavation/treatment/disposal, or *in-situ* techniques such as bioremediation, soil vapor extraction, bioventing, chemical oxidation/reduction, and solidification/stabilization.

As described in Section 1.2.1, physical remnants that were discovered from the past disposal have been removed. No additional physical remnants (such as buried containers) of past waste disposal at Site 07 have been located and regions of significantly elevated COC concentrations in surface or subsurface soil were not identified. Furthermore, no unacceptable risks are associated with surface or subsurface soil at Site 07. Therefore, source control and treatment technologies will not be retained for further consideration.

2.7.4 Ground-Water Containment Actions

Ground-water containment technologies are used to contain a migrating contaminant plume. Typically, hydraulic control technologies or vertical barriers are used to achieve ground-water containment.

2.7.4.1 Hydraulic Controls

Hydraulic control technologies for ground water can include the use of extraction wells, injection wells, or recovery trenches. Extracted ground water must be treated and discharged to an acceptable receiving body (typically a surface water or a wastewater treatment facility). Hydraulic controls are designed to reduce mobility of COC in ground water. Theoretically, to achieve long-term control, ground-water extraction systems must be operated in perpetuity. These technologies are typically used in conjunction with ground-water treatment technologies (Section 2.7.5).

Extraction Wells

Ground-water extraction wells used for hydraulic control are typically installed along the boundary of a site, downgradient of a source area or plume. In general, ground water is extracted at sufficient flow rates to achieve a hydraulic gradient flow reversal, thereby preventing the migration of affected ground water from a site. Other than hydraulic control, ground-water extraction wells can also be used for source treatment remedies in conjunction with *ex-situ* ground-water treatment technologies (Section 2.7.5).

- **Effectiveness** - Ground-water extraction will not be effective for the hydraulic control of the COC plumes at Site 07. This form of hydraulic control involves installing multiple extraction wells on the downgradient side of the plume operated at relatively high pumping rates in order to create a hydraulic flow reversal which will halt plume migration. Extraction wells installed downgradient of Site 07 would not be feasible due to the presence of Allen Harbor. Furthermore, extraction wells installed along the shoreline of Site 07 also would be ineffective due to the presence of the harbor (i.e., any extraction wells placed near the shoreline of the site would draw in substantial volumes of harbor water thus reducing the effectiveness for controlling ground water and dramatically increasing the costs by unnecessarily treating larger volumes of "clean" water). The saline harbor water may also complicate the subsequent ground-water treatment processes.

  Ground-water extraction can be used as part of a source treatment technique (i.e., "pump-and-treat"). The effectiveness of a hydraulic containment system through ground-water extraction is dependent, in part, on the hydraulic conductivity of the media. Based upon data from the Phase III RI, the high hydraulic conductivity of the upper sand unit appears to be amenable to ground-water extraction; however, unacceptable risks at Site 07 are generally associated with the deep and bedrock ground-water zones. Elevated levels of COC in shallow ground water were identified in the plume extending from MW07-26S to MW07-21S; however, as previously described, a low pumping rate would be required due to the proximity to the harbor. Due to the low hydraulic conductivity of the middle silt unit and the lower sand/till unit, ground-water extraction in the deep aquifer may only be effective at low pumping rates. Low pumping rates may also be required in order to minimize the potential to increase the salt content of ground water in the source area. Saline ground water may be more difficult to treat. Extraction of bedrock ground water would have limited effectiveness due to the technical difficulties for adequately predicting the size and location of bedrock fractures.

- **Implementability** - Installation of a system of extraction wells involves established construction practices. Vendors and equipment are readily available. A treatment system would be required for the extracted ground water. If onsite treatment is performed, then an acceptable point of discharge for the treated ground water would have to be established. A ground-water extraction system may not be technically implementable along the shoreline of the site because of the water head of Allen Harbor which would reduce the ability to control the plume. An extraction system located in the source area would be implementable at low flow rates.

Ground-water extraction wells may be able to achieve hydraulic control of a ground-water source area. This technology will not be effective for capturing the entire plume due to the proximity to Allen Harbor and the presence of COC in bedrock fractures. Extraction wells for hydraulic control of the entire site plume will not be retained for further consideration; however, extraction wells will be retained for further consideration as a source treatment option in conjunction with ground-water treatment technologies.

Injection Wells

Injection wells are used to achieve hydraulic control by establishing recirculation patterns sufficient to modify the direction and/or velocity of plume migration. Injection wells can be used in conjunction with extraction wells for greater control of ground-water flow.

- **Effectiveness** - Injection wells can be effective for redirecting a ground-water plume to an area where it can be more efficiently extracted. However, as described above, ground-water extraction was not retained except as a source area treatment technique.

- **Implementability** - Injection wells can be installed using established procedures. Vendors and equipment are commercially available. Regulatory approval for injection wells can be difficult to obtain if the extraction wells are equally effective without injecting water into an aquifer. Low injection rates would be required due to the low conductivity of the silt, lower sand, and till layers.

Injection wells can be effective in conjunction with extraction wells. Ground-water extraction wells (which were retained as a source-area treatment option) can be effective without injection wells. Therefore, injection wells will not be retained for further consideration.

Recovery Trench

Recovery trenches, or subsurface drains, are filled with a high-permeability backfill (e.g., gravel) and perforated piping which are used as conduits to convey and collect ground water via gravity flow. Recovery trenches are typically installed along the boundary of a site, hydraulically downgradient of a source area or plume. Ground water is extracted from the trenches at sufficient flow rates to achieve a hydraulic gradient flow reversal, thereby preventing migration of affected ground water from a site. Trench drains are highly effective where a continuous hydraulic barrier needs to be maintained, difficult hydrogeologic conditions exist, or low water-bearing units dominate the area. A trench drain provides a continuous hydraulic barrier which can intercept the width of the capture zone if designed to do so. Maintenance of a trench drain system is generally low because siltation does not effect a trench as much as an extraction well due to the redundancy of the design of a trench. The main disadvantage of subsurface drains is the potentially prohibitive costs of shoring, dewatering, and excavation (including handling of excavated soil containing COC) during installation. These costs and technical difficulties may be offset somewhat through variations in construction techniques.

- **Effectiveness** - The effectiveness of a trench drain system at Site 07 is uncertain due to its proximity to Allen Harbor (located on the downgradient side of the site), which would introduce a substantial volume of surface water relative to site ground water. In general, recovery trenches can be effective for collecting shallow ground water to achieve hydraulic containment; this technique cannot used for deep or bedrock ground-water control (where the highest COC concentrations and risks have been identified). If used to control the shallow ground-water plume between MW07-26S and MW07-21S, some design difficulties would be encountered because an impermeable barrier (e.g., sheet pile wall, flexible membrane) would be required on the downgradient (harbor) side of the trench drain in order to minimize contact with the harbor water.

- **Implementability** - This is a proven technology and the required services are readily available. Pre-design investigations may be necessary to refine specific parameters. Recovery trench installation is generally limited in depth to 25 to 30 ft below grade. Ground water which is extracted from a recovery trench will have to be treated prior to disposal. As discussed for extraction wells, a ground-water treatment system would have to be constructed and an acceptable point of discharge would have to be established. The design of a recovery trench may require an impermeable barrier on the downgradient side in order to prevent drawing in, and unnecessarily treating of, water from Allen Harbor.

- **Cost** - Costs can be high depending upon the amount of shoring and the depth of excavation required.

A recovery trench would not be effective for the hydraulic control of deep or bedrock ground water. A recovery trench would have limited effectiveness for collecting the shallow ground-water plume between MW07-26S and MW07-21S due to the proximity of Allen Harbor. Therefore, recovery trenches will not be retained for further consideration.

2.7.4.2 Vertical Barriers

Vertical barriers are relatively impermeable subsurface walls installed to limit lateral migration of COC from a site or to divert ground water to limit contact with COC. These vertical barriers or walls are generally more effective when they are keyed into an impervious clay or competent bedrock layer. However, when the preferred horizontal geologic strata (i.e., a low permeable material) is not present, a partial vertical barrier can influence local hydrogeologic regimes, thus achieving partial hydraulic control of the system. Vertical barriers can be placed upgradient, downgradient, or completely surrounding a site or around a selected area within a site. Perimeter barrier walls which surround a site or selected area must be used in conjunction with capping or ground-water extraction in order to prevent the build-up of ground water within the enclosed area. Vertical barriers will not be retained as a perimeter containment technology because (1) capping has not been retained for further consideration, (2) ground-water extraction can be effective without additional containment measures, and (3) the HHRA did not identify unacceptable risks associated with ground-water migration. Vertical barriers may be effective when used in conjunction with other treatment technologies in order to control the ground-water flow regime.

<u>Soil-Bentonite Slurry Wall</u>

Soil-bentonite slurry walls are the most commonly used vertical barrier system because they are relatively inexpensive and easy to construct. Slurry walls are typically installed by excavating a narrow trench while simultaneously pumping in a bentonite slurry. In areas having limited access, slurry walls can be installed by deep soil mixing where the slurry wall is constructed *in-situ*, without trench excavation, by injecting the slurry through a multiple auger unit. For standard trench excavations, the slurry hydraulically stabilizes the trench walls to prevent collapse and, at the same time, creates a relatively impermeable coating (filter cake) along the inside of the trench walls. Once the trench is excavated to the desired depth, a blend of soil and bentonite is backfilled into the trench up to the ground surface. After the wall is completely installed, the slurry is allowed to consolidate for several weeks. Slurry walls require no maintenance other than excavation and replacement of areas where surficial desiccation cracks appear. Conditions that may negatively affect the impermeability of slurry walls include low pH, heavy metals, solvents (e.g., chlorinated hydrocarbons) and electrolytes (e.g., sodium, calcium). The impermeability of slurry walls can be greatly increased when used in conjunction with a synthetic membrane installed within the trench. This membrane can either be used to line the trench as a single-layer or the slurry mixture can be poured onto the membrane in order to line both sides of the excavated trench.

- **Effectiveness** - A slurry wall can be effective for controlling the lateral movement of shallow and deep ground water at the site, although the presence of chlorinated organic compounds and the proximity to harbor (salinity) may decrease the effectiveness and/or the design life of the wall. Specialized slurry mixtures and/or addition of low-permeability liners on either side of the slurry wall may extend the effective life of the barrier. A slurry wall will not be effective in containing ground-water flowing through bedrock fractures. The slurry wall can be used in conjunction with some *in-situ* ground-water treatment technologies (e.g. *In-Situ* Permeable Reaction Walls - Section 2.7.5.1).

- **Implementability** - Slurry wall construction technology is well-established and vendors are readily available. Some pre-design investigations may be required to compensate for the construction difficulties which would result from the salinity and solvent content of site ground water.

In general, installation of a slurry wall can be effective either for controlling shallow and/or deep ground-water flow and may be useful in conjunction with an *in-situ* ground-water treatment technology. Slurry walls would be implementable; however, the salt and solvent content of site ground water is likely to reduce the effectiveness of this technology. Therefore, slurry walls will not be retained for further consideration.

Sheet Pile Wall

A sheet pile wall can be installed using steel sheets driven into the ground using either a drop hammer or a vibratory hammer. The interlocking sheet pile sections form a relatively impermeable barrier to ground-water flow. The driving force allows the sheet piles to partially seal as soil is forced into the edge interlocks. Grout or hydrophilic seal material can be pumped into the sheet connection joints to improve the effectiveness of the wall.

- **Effectiveness** - Steel sheet piling is an established technology for constructing hydraulic containment walls. Sheet pile walls can also be effective for controlling or redirecting both shallow and deep ground-water flow. This technology will not be effective for controlling bedrock ground water. This technique can be used with other *in-situ* ground-water remediating technologies (such as *In-Situ* Permeable Reaction Wall systems) by channeling affected ground water towards an *in-situ* treatment zone. The presence of rock and metal debris can render the wall ineffective if they cause the piles to deflect or bend when being driven. The potential for pile deformation increases with increased depth of installation. Cutting edges can be welded on to the piling to minimize potential pile refusal. Typically, steel sheet pile requires little maintenance and can have a design life of up to 40 years. However, at Site 07 salt water intrusion into the intermediate and deep ground-water environment can reduce the long-term effectiveness of a sheet pile barrier. Protective measures (e.g., epoxy coating, cathodic protection, specialized grades of steel) can be taken to extend the effective life of the piling.

- **Implementability** - This is a proven technology and should be implementable. Vendors are readily available. Adequate access/area is available for the required heavy machinery and storage of materials during construction. As determined during the Site 09 (Allen Harbor Landfill) investigations, an above-grade sheet pile wall would not be acceptable along the shoreline of Allen Harbor (due to aesthetic concerns) and due to increased susceptibility to corrosion. Installation of a sheet pile wall below grade will be implementable.

- **Cost** - Costs can be high depending upon the length and depth required for the sheet piling.

Construction of a sheet pile wall can be effective and implementable for hydraulic channeling and will be retained for further consideration in conjunction with *in-situ* ground-water treatment technologies.

Grout Curtain

Grout injection can be used to install an impermeable vertical barrier around a source area. Grout can be injected into high permeable soil layers (e.g., gravel lenses). The grouting process creates overlapping impermeable blocks to create a barrier to horizontal ground-water flow.

- **Effectiveness**—A grout curtain would not be effective for controlling horizontal ground-water migration at Site 07 due to lack of coarse-grained materials within the site (particularly in the intermediate and deep ground water regions which consists of silt and lower sand/till units). This technology cannot be effectively implemented over large areas due to the limited area of influence of the injection wells and the difficulties in verifying the integrity of the grout barrier.

- **Implementability**—A grout curtain is not an established ground-water containment method and few vendors are available.

A grout curtain will not be effective or easily implementable for controlling the horizontal migration of ground water at the site due to the design difficulties and the lack of a compatible geology for its implementation. Therefore, this technology will not be retained for further consideration.

2.7.5 Ground-Water Treatment Actions

These ground-water treatment technologies include *in-situ* options (Section 2.7.5.1) as well as various *ex-situ* options (Sections 2.7.5.2 through 2.7.5.4) which would be used in conjunction with ground-water extraction.

2.7.5.1 *In-Situ* Treatment

Many ground-water treatment processes can be applied *in-situ*. These can include active ground-water remediation techniques such as *in-situ* bioremediation, aquifer air sparging, and Vacuum-Vaporizer Wells (an *in-situ* air stripping well) as well as passive ground-water remediation such as permeable reaction walls.

Aerobic Bioremediation

In-situ, aerobic bioremediation can be applied to degrade certain organic compounds by employing intrinsic (naturally occurring) aerobic (oxygen using) bacteria that will use the COC as their carbon source. This technology is typically applied to petroleum contamination. The main advantage of *in-situ* bioremediation is that COC in the subsurface soil and ground water can be treated without soil excavation. *In-situ* bioremediation can also be applied to impacted ground water with equal effectiveness although there are additional considerations such as the hydraulic control of the treatment zone. Typically, a combination of oxygen (as hydrogen peroxide) and nutrients (e.g., nitrogen, phosphorus) are injected into the headwaters of the ground-water plume. This promotes the growth of the natural bacteria population in the subsurface. For the co-metabolic degradation of chlorinated VOC, a primary substrate such as methane, toluene, or phenol has to be added. The end result bioremediation is the destruction of organic COC into carbon dioxide, water, and biomass (bacteria).

- **Effectiveness** - Aerobic bioremediation can be effective for the treatment of petroleum products; this technology has not been proven to be effective for remediating chlorinated COC in ground water.

- **Implementability** - While the actual installation of the wells and equipment is not difficult, controlling the migratory path of the terminal electron acceptor (oxygen), nutrients, and primary substrate is very difficult. Mass transfer limitations (ensuring that oxygen and nutrients reach the bacteria) are the primary difficulty for achieving successful bioremediation. With respect to the aerobic degradation of chlorinated COC, injection of some of the primary substrates, such as toluene and phenol, into subsurface would not be desirable and regulatory acceptance may be difficult to obtain.

In-situ, aerobic bioremediation to treat chlorinated COC in ground water is not effective and may not be implementable in an administrative sense; therefore, this technology will not be retained for further consideration.

Anaerobic Biodegradation

In-situ, anaerobic bioremediation is an innovative technology which is designed to degrade chlorinated organic compounds by employing intrinsic (naturally occurring) microorganisms (bacteria). Chlorinated organic compounds such as TCE can be degraded biologically under anaerobic conditions. The main advantage of *in-situ* bioremediation is that COC in subsurface soil and ground water can be treated without soil excavation. *In-situ* bioremediation can also be applied to affected ground water with equal effectiveness although there are additional considerations such as the hydraulic control of the treatment zone. Typically, an organic substrate (e.g., sodium benzoate, acetate) is injected into the subsurface which the microorganisms will then consume as a carbon source, in the process, reduce the concentration of dissolved oxygen in ground water. Under this anaerobic condition, the microorganisms will then begin to consume the chlorinated COC as an oxygen substitute. The end result anaerobic bioremediation is the destruction of chlorinated organic COC into carbon dioxide, water, innocuous salts, and biomass.

- **Effectiveness** - Anaerobic bioremediation is an innovative technology; some case studies have shown this to be effective for reducing the concentrations of chlorinated organic compounds in ground water. A treatability study may be required to confirm that the site conditions and intrinsic bacteria can degrade the COC. Incomplete degradation of some chlorinated COC (e.g., PCA, TCE) may result in more toxic by-products (e.g., VC). The effectiveness of this process would be evaluated through a long-term monitoring program.

- **Implementability** - While the actual installation of the wells and equipment is not difficult, mass transfer limitations (ensuring that the injected compounds reach the bacteria) are the primary difficulty for achieving successful bioremediation.

Although an innovative technology, *in-situ*, anaerobic bioremediation may be effective for reducing chlorinated COC concentrations in ground water. A treatability study may be required to confirm the effectiveness of this process as well as to determine the optimal placement of injection wells to minimize mass transfer problems. Therefore, this technology will be retained for further consideration.

<u>Permeable Reaction Wall</u>

The permeable reaction wall technology is designed to degrade chlorinated organic compounds such as PCE, TCE, 1,2-DCE, VC, and TCA in ground water. The technology uses a porous media containing an iron-based catalyst that degrades the compounds by abiotic or biological processes as they pass through the wall. Low hydraulic conductivity cut-off walls such as slurry walls or sheet pile walls are installed adjacent to the *in-situ* reactors to direct ground-water flow through the high conductivity gaps. Remediated ground water exits the downgradient side of the reactive wall. The technology is essentially passive in that the *in-situ* reactors are intended to function with little or no maintenance for extended periods. Reaction wall systems can be built in several configurations (e.g., single gate, multiple gate, V-shaped funnel, U-shaped funnel, etc.). The iron-based catalyst requires periodic maintenance (e.g., mixing) and/or replacement during extended remediations (e.g., once every 5 years).

- **Effectiveness** - The technology is largely in the demonstration stage (in conjunction with EPA's SITE program). Currently, *In-Situ* Permeable Reaction Wall systems have been installed at five demonstration sites (pilot studies) and full-scale variations of this technology have been implemented at six sites. This technology may be effective for passively degrading VOC in shallow and deep ground water. This technology may not be effective for certain organic compounds such as benzene and 1,2-DCA; however, these compounds were infrequently detected (Table 2-4) at Site 07.

- **Implementability** - This technology may be implementable at the site due to its passive nature where in ground water can be redirected toward a zone of high hydraulic conductivity instead of attempting to actively contact areas of elevated COC concentrations in the subsurface. When used in conjunction with vertical barriers, this technology requires little excavation to place a reaction wall in the subsurface. This technology will not be implementable for bedrock ground water.

The *In-Situ* Permeable Reaction Wall technology may be effective and implementable for degrading some organic COC in shallow and deep ground water at Site 07. Therefore, this technology will be retained for further consideration.

Aquifer Air Sparging/Soil Vapor Extraction

Aquifer Air Sparging (AAS) refers to the application of fresh air injection for the remediation of ground water within the saturated zone. Compressed air is forced through "sparging" wells into the saturated zone. As the air rises through the aquifer matrix, VOC will partition from the liquid phase (ground water) into the gas phase (injected air). The VOC vapors continue to be transported with the air through the ground water and into the unsaturated zone. AAS is often used in conjunction with Soil Vapor Extraction (SVE) which involves the vacuum extraction of soil gas located within the vadose zone (thereby capturing the injected air containing the VOC). At the same time, AAS will increase dissolved oxygen concentrations in ground water and oxygen concentrations in the unsaturated zone; this will promote the biodegradation of aerobically susceptible compounds by indigenous bacteria. Some remediation of vadose and saturated soil can also be initiated by desorbing VOC through either increased ground-water movement (resulting from the pressure of the injected air) or by disrupting the subsurface VOC equilibrium and creating a driving force for transferring VOC from soil to either ground water or soil gas (which will then be captured by the AAS/SVE system). Application of air sparging is limited by the heterogeneity and permeability of the soil matrix as well as the volatility characteristics of the target COC.

Soil matrix heterogeneity: Horizontal barriers with low air permeability in the saturated or unsaturated zone can restrict vertical air flow (e.g., continuous clay lenses). This may increase the extent of horizontal migration of the contaminant plume. The lateral discontinuous lenses of silty clay could impede the vertical migration of air, thereby decreasing the VOC removal rate from the saturated and unsaturated zones. Fractures in a soil matrix may decrease the effectiveness of the sparging system by allowing air to flow along preferential pathways instead of dispersing evenly throughout the sparging well's treatment radius.

Soil matrix permeability: An aquifer conductivity of at least 10^{-5} cm/sec and a soil air permeability for the unsaturated zone greater than 10^{-10} cm^2 is required for AAS to be effective. A low ratio of horizontal permeability to vertical permeability is also preferable.

Volatility characteristics: The vapor pressure and Henry's law constant are used as the parameters to determine the volatility of the compounds. Generally, a chemical with a vapor pressure greater than 0.5 to 1.0 mm Hg (at 20°C) and a Henry's constant of at least 10^{5} atm-m^3/mole is required for the removal of the compound from ground water.

- **Effectiveness** - AAS/SVE is an emerging technology for hazardous waste cleanups and a treatability study would be necessary in order to identify the effectiveness at Site 07. AAS/SVE systems will perform effectively in removing VOC with Henry's constants greater than 10^{-5} atm-m^3/mole. The COC at Site 07 are volatile compounds which should be amenable to AAS/SVE. AAS may not be effective for treating bedrock ground water because a permeable, relatively homogeneous matrix is required (free from a high degree of preferential pathways such as bedrock fractures—also, the subsequent collection of the injected air by an SVE system would be complicated by potential channeling of the air through bedrock fractures to areas outside the anticipated radius of influence). AAS/SVE will not be effective for treating the deep or bedrock ground water in most regions of Site 07 because these zones are located below a low-permeability silt layer. Injecting air into the lower sand/till unit would result in the air spreading out along the underside of the low-permeability silt unit. The air containing COC could not be recaptured through an SVE system. AAS could be employed for the treatment of shallow ground water; however, the shallow ground-water table may prohibit the use of the SVE system necessary to recapture the injected air.

- **Implementability** - AAS is implementable for shallow and deep ground water. AAS would be difficult to implement into bedrock. Vendors and equipment are readily available.

AAS/SVE will not be sufficiently effective for treating shallow or deep ground water due to the shallow ground-water table in most areas and the presence of a low permeability silt layer across most of the site. AAS/SVE would also be difficult to implement for the treatment of bedrock ground water due to potential channeling through bedrock fractures as well as the low permeability of the overlying silt layer. Therefore, this technology will not be retained for further consideration.

Vacuum-Vaporizer-Well

Vacuum-Vaporizer Wells are an innovative, *in-situ* method for the removal of VOC from ground water. VOC in ground water are stripped by air in a vacuum pressure field created in a specialized screened well (vacuum-vaporizer-well). A Vacuum-Vaporizer Well is screened in two sections: (1) at the aquifer bottom, and (2) at the ground-water surface. The upper, closed part of the well is maintained below atmospheric pressure by a ventilator. This lifts the water level within the well casing. The fresh air for the upper part of the well casing is introduced through a fresh air pipe: the upper end is open to the atmosphere, and the lower end terminates in a pinhole plate. The height of the pinhole plate is adjusted such that the water pressure is lower there than the atmospheric pressure. Therefore, the fresh air is drawn into the system. The reach between the pinhole plate and the water surface in the well casing is the stripping zone, in which an air bubble flow develops. The rising air bubbles produce a pumping effect, which moves the water up the well and causes a suction effect at the well bottom. Additionally, soil air may be drawn from the surrounding unsaturated zone as well. Stripped air and possibly soil air are transported through the ventilator. This offgas can be treated with activated carbon prior to venting to the atmosphere. The treated ground water exits from the upper screen and re-enters the aquifer. A recirculation zone (potentially extending several dozen ft from the well) can develop between the lower (intake) and upper (exit) screened intervals. This recirculation zone can enhance the removal of VOC within the well's radius of influence.

- **Effectiveness** - Vacuum-Vaporizer Wells can be effective for the removal of VOC from shallow and deep ground water without the need for ground-water extraction. The radius of influence of a Vacuum-Vaporizer Well depends on site-specific conditions such as the permeability of the soil matrix; however, demonstration sites and vendor estimates have suggested a radius of influence for each well between 35 and 80 ft. This technology may not be effective for removing VOC from bedrock ground water due to the technical difficulties in locating and compensating for preferential flow paths through bedrock fracturing.

- **Implementability** - Vacuum-Vaporizer Wells are still considered to be an innovative technology and few sites have employed this technology. Vendors are available for installation, maintenance, and for performing an initial operational test at the site. Vacuum-Vaporizer Wells have been implemented in conjunction with EPA's SITE program for treating chlorinated VOC. A treatability study may be required to determine the effectiveness of this technology at Site 07.

- **Cost** - Due to the specialized well construction, installation and operational costs for Vacuum-Vaporizer Wells are high as compared to similar *in-situ* air stripping techniques such as AAS/SVE.

Although a treatability study may be required to confirm the effectiveness and implementability of Vacuum-Vaporizer Wells at Site 07, this technology may be effective and implementable for removing VOC from shallow and deep ground water. Therefore, this technology will be retained for further consideration.

2.7.5.2 *Ex-Situ* Treatment - Physical

Reverse Osmosis

Reverse Osmosis (RO) is used to reduce the concentration of dissolved solids, both organic and inorganic, by use of a semi-permeable membrane under hydrostatic pressure. The primary objective of the RO process is to remove ionic species. Osmosis is the process where the solvent (i.e., water) flows from a high concentration solution through a semipermeable membrane to a low concentration solution (thereby concentrating the contaminants). The RO process separates ions from water by opposing the natural osmotic movement through the use of an applied pressure that is greater than the osmotic pressure.

- **Effectiveness** - For hazardous waste streams, RO is primarily limited to processing low flow streams containing highly toxic compounds. Typical membranes are impermeable to most inorganic species and some organic compounds. RO would be effective for reducing the salt content of extracted ground water (as a potential pretreatment process). RO would not be effective for removing organic compounds.

- **Implementability** - High pressures are required for RO systems. However, the required equipment and services are readily available.

- **Cost** - The costs associated with RO are high and may be cost-prohibitive for treating large volumes of water.

RO will not be effective for treating the COC at Site 07 (VOC). RO is not cost-effective for treating large volumes of water. Therefore, RO will not be retained for further consideration.

Ultrafiltration

Ultrafiltration is a membrane filtration process that separates high molecular weight solutes or colloids from a solution or suspension. Ultrafiltration works by employing a porous membrane to separate the two types of solutes (one of a molecular size too small to be retained by the membrane, and the other of a larger size allowing 100% retention). A hydrostatic pressure, typically 10 to 100 psig, is applied to the upstream side of the supported membrane, and the large-molecule solute or colloid is retained (rejected) by the membrane. A solution of retained solute is collected as a product from the upstream side, and a solution of small-molecule solute and solvent is collected from the downstream side of the membrane.

- **Effectiveness** - Ultrafiltration systems have been primarily used to treat industrial products or industrial wastes. This will not be effective at Site 07 because the COC in ground water are low molecular weight compounds.

- **Implementability** - The process has been successfully applied to both homogeneous solutions and colloidal suspensions, which are difficult to separate practically by other techniques. To date, commercial applications have been entirely focused on aqueous media.

- **Cost** - The costs associated with ultrafiltration are high and can be considered cost-prohibitive for large volumes of water.

Ultrafiltration will not be effective for the COC at Site 07; therefore, this technology will not be retained for further consideration.

Filtration

Filtration of suspended solids is a standard pretreatment process to remove particles which would clog subsequent treatment systems and shorten their useful life. The most common method of filtration is through a sand or multimedia filter. Granular media filtration is typically used for treating aqueous waste streams. The filter media consists of a bed of granular particles. The bed is contained within a basin and is supported by an underdrain system which allows the filtered liquid to be drawn off while retaining the filter media in place. As water laden with suspended solids passes through the bed of the filter medium, the particles become entrapped on top of, and within, the bed. This either reduces the filtration rate at a constant pressure or increases the amount of pressure needed to force the water through the filter. In order to prevent plugging, the filter is occasionally backwashed at a high velocity to dislodge the particles.

- **Effectiveness** - Filtration is effective in removing some suspended particulates; however, it will not remove some small colloids or dissolved components which are able to pass through the filter bed. If it is determined that ground water contains suspended particulates which will adversely affect subsequent treatment processes, this technology would be an effective pretreatment step.

- **Implementability** - Filtration is a proven technology and readily implementable. Vendors and equipment are readily available. This technology will be implementable for ground water.

Filtration is both effective and implementable at removing suspended particles as a pre-treatment for most onsite ground-water treatment processes. This technology will be retained for consideration along with other onsite ground-water treatment processes which require the removal of suspended particles prior to treatment.

Precipitation/Flocculation/Sedimentation

Precipitation is a physical-chemical process whereby some or all of a substance in a solution is transformed into a solid phase. It is based on alteration of the chemical equilibrium relationships affecting the solubility of inorganic species. Flocculation is a process in which small, unsettleable particles suspended in a liquid medium are made to agglomerate into larger, more settleable particles. Generally lime, sodium sulfide, aluminum, or iron salts (e.g., ferric chloride, ferrous sulfate) are added for flocculation and subsequent precipitation. The suspended particles are settled in a sedimentation chamber by gravity. The contaminants are not destroyed in this treatment process, but are removed as a waste sludge requiring subsequent disposal.

- **Effectiveness** - Precipitation and flocculation are well established technologies and have been proven highly effective in removing suspended solids and metals in wastewater. If the dissolved metals present in the ground water at Site 07 would present an adverse effect on *ex-situ* ground-water treatment processes, then precipitation could potentially be used as a pretreatment process. The sludge generated during this treatment would require disposal. This technology by itself will not be a treatment solution for ground water at the site. However, this technology would be an effective pretreatment process.

- **Implementability** - The process requires mixing and settling tanks, and chemicals which are commercially available. This technology poses minimum safety and health hazards to field workers. This technology can be used in ambient conditions which makes it easily implementable.

These processes would be effective and implementable as a pretreatment process for alternatives which employ ground-water extraction. Therefore, this technology will be retained for further consideration.

Air Stripping

During air stripping, VOC in ground water are transferred to the gaseous phase in a countercurrent, induced-draft tower. Generally, organic compounds with a Henry's Law constant greater than 10^{-5} atm-m^3/mol can effectively be removed by air stripping (Brown et al., 1991 and Lyman and Rosenblatt, 1992). The factors governing the removal of specific organic compounds from ground water include temperature, pressure, air-to-water ratio, and the surface area available for mass transfer.

- **Effectiveness** - This treatment technology would be effective for removing VOC from extracted ground water. However, the packing material in the air stripping tower could become clogged by the precipitation or scaling from dissolved metals and/or salt in ground water extracted from Site 07. Ground-water in the southern and eastern portions of Site 07 has a high salt content and may not be amenable to air stripping without pretreatment. Desalination processes (e.g., RO) can be cost-prohibitive for large volumes of water. Air stripping would have to be used in conjunction with pretreatment processes such as coagulation/flocculation. VOC would not be destroyed through air stripping; rather, offgas from the air stripping tower would have to be treated (e.g., GAC) prior to discharge to the atmosphere. An acceptable point of discharge would have to be identified for the treated ground water.

- **Implementability** - This technology is implementable at Site 07. This is a proven technology and has been implemented in the past at many other sites. The vendors and equipment required are commercially available.

Air stripping used along with ground-water extraction system would be effective for removing volatile COC from ground water provided that adequate pretreatment processes can be identified. This technology will be retained for further consideration.

Activated Carbon Adsorption

Carbon used for adsorption is usually treated ("activated") to produce a product with a large surface to volume ratio, thus exposing a large surface area for active adsorption. Granular Activated Carbon (GAC) can readily adsorb most organic compounds and some inorganic compounds from both aqueous and gaseous phase. Over a period of time, the sites available for adsorption become saturated and the efficiency is reduced. The spent GAC is then regenerated or disposed.

- **Effectiveness** - GAC would be effective for removing organic COC from extracted shallow, deep, and bedrock ground water from Site 07. It would also be effective as an air treatment process for treating volatile COC laden air effluent from air stripping system used to treat extracted ground water.

- **Implementability** - This technology is well-proven and easily implementable both as an aqueous treatment process or as an air effluent post-treatment process for air stripping system. Vendors and necessary equipment are readily available. The disposal or regeneration of GAC must be considered when implementing this technology. Prior to GAC treatment, as an aqueous treatment process, pretreatment may be required for removal of natural organic matter, suspended solids, and/or metals.

- **Cost** - GAC can be expensive as a stand-alone treatment process due to the expenses associated with carbon purchase and regeneration/disposal. GAC is often better suited as a final "polishing" step in a larger treatment train.

Activated carbon adsorption is both effective and implementable for the removal of organic COC from extracted ground-water (or for treating offgas air from another treatment technology). Liquid and vapor-phase activated carbon adsorption will be retained for further consideration.

Ultraviolet Oxidation

Ultraviolet (UV) oxidation utilizes UV light combined with the addition of an oxidant, usually either as ozone or hydrogen peroxide (H_2O_2), or both, to produce a highly oxidative environment. The UV light serves to enhance the ozone and hydrogen peroxide's reactivities by:

- transforming them to highly reactive hydroxyl ($OH^{\bullet}$) radicals;
- raising the VOC molecules to higher energy levels;
- initially attacking and breaking down the VOC.

The end products of the complete process reactions are carbon dioxide, water, and innocuous salts. Residual ozone must be destroyed by a catalytic ozone decomposer unit to reduce discharge levels to meet acceptable air quality standards.

- **Effectiveness** - UV oxidation is a relatively innovative technology for the treatment of hazardous wastes; however, it is effective for destroying a variety of organic compounds, including those detected in the ground water samples at Site 07. Particulates in the ground water would decrease the intensity of the UV light, thereby reducing the process efficiency; therefore, pretreatment with filtering or sedimentation would be required. The high salinity of the ground water at Site 07 will likely limit the effectiveness of a UV oxidation system due to the eventual formation of deposits (scaling) on the lamp array. In order to compensate for this effect, either the ground water would have to be pretreated to remove salt (which can be cost-prohibitive) or the UV lamps would require continual cleaning.

- **Implementability** - UV oxidation is likely to be unwieldy when treating large quantities of water. A UV/H_2O_2 system would not be highly operator intensive, however, skilled personnel would be required throughout the remediation process, particularly if ozone is employed. The UV lamps will require periodic cleaning to remove scaling and other deposits. This can be accomplished with either in-line mechanical wipers or chemical cleanings.

- **Cost** - UV oxidation processes which employ ozone can be more expensive than those which use hydrogen peroxide only because ozone must be generated onsite and then must be destroyed in the offgas. The installation and O&M costs can be high for treating large volumes of water and the process may require pretreatment of the ground water (for removal of turbidity and/or salinity).

UV oxidation can be effective in destroying the organic COC in ground water. However, UV oxidations systems are not recommended for saline or brackish water (e.g., greater than 7‰ salinity). This technology will not be retained for further consideration.

2.7.5.3 *Ex-Situ* Treatment - Chemical

Oxidation/Reduction

Oxidation/reduction ("redox") reactions are those in which electrons are transferred so that the oxidation state of at least one reactant is raised while that of another is lowered. In chemical oxidation, the oxidation state of the treated compound(s) is raised. Common oxidants include potassium, permanganate, hydrogen peroxide, ozone, calcium/sodium hypochlorite, and chlorine gas.

Chemical reduction involves addition of a reducing agent which lowers the oxidation state of a substance in order to reduce toxicity or solubility or to transform it to a form which can be more easily handled. Commonly used reducing agents include sulfite salts (e.g., sodium bisulfite, sodium metabisulfite, sodium hydrosulfite), sulfur dioxide, and the base metals (e.g., iron, aluminum, and zinc).

- **Effectiveness** - Chemical redox can be an effective way of pretreating COC in the ground water prior to biological treatment; compounds which are refractory to biological treatment can be partially oxidized, making them more amenable to biological oxidation. This technology may be used in conjunction with ground-water extraction and other treatment process such as bioremediation for organic COC and precipitation for metals.

- **Implementability** - Chemical redox is implementable at Site 07 along with other treatment technologies. Vendors and equipment are readily available.

- **Cost** - The cost of installation and operation of this technique may be very high.

Chemical redox may be effective and implementable as a pretreatment process for alternatives which employ ground-water extraction. However, the cost of installation and operation of this technique may be very high as compared to other technologies which may be equally effective. Therefore, chemical redox will not be retained for further consideration.

Incineration

Incineration employs high temperature oxidation under controlled conditions to destroy organic compounds in liquid, gaseous, and solid waste streams and can be implemented onsite or offsite. The most common thermal destruction technologies for the treatment of hazardous wastes include liquid injection, rotary kiln, fluidized bed, and multiple hearth incineration. The technology which is chosen is determined from the types of waste streams and contaminants to be treated. Several innovative incineration technologies are also becoming commercially available. Air pollution control measures are necessary for reducing potentially undesirable emissions to the atmosphere.

- **Effectiveness** - Incineration is a highly effective, final treatment for a waste streams containing with organic compounds. Depending upon the process application and the types of compounds being treated, a 99.9999% destruction of organic compounds can typically be achieved. Air pollution control equipment can reduce the emissions into the atmosphere.

- **Implementability** - This is a proven technology for various organic compounds and can be implemented but may require pretreatment of ground water to remove solids. Burn tests would be required to confirm the destruction of the COC to regulated levels. This technology would not be implementable onsite due to Rhode Island's coastal regulations as well as anticipated public concerns over incineration near residential neighborhoods. An offsite incinerator facility which could accept hazardous wastes would have to be located.

- **Cost** - Incineration of large volumes of water is considered to be cost-prohibitive.

Incineration can be highly effective for destroying organic COC. However, incineration of large volumes of ground water is cost-prohibitive, in comparison to other effective *ex-situ*, ground-water treatment technologies. Therefore, incineration will not be retained for further consideration.

Ion Exchange

Ion exchange is a process in which target ions are removed from an aqueous phase though exchange with relatively harmless ions held by an ion exchange material. Ion exchange materials consist of synthetic organic resins containing ionic functional groups to which exchangeable ions are attached. These synthetic resins are structurally stable, exhibit a high exchange capacity, and can be tailored to perform in specific cases.

- **Effectiveness** - This technology would be an effective *ex-situ* treatment process for the removal of some metals from ground water. Ion exchange would not be effective for the removal of organic COC. Generally, the flow rates that can be handled by this technology are around 40 to 50 gal/min.

- **Implementability** - This is an established technology and can be implementable for low volumes of water. Operational difficulties can be encountered at high flow rates.

- **Cost** - Ion exchange can be expensive for treating large volumes of water as compared to other technologies (e.g., metals precipitation).

Ion exchange can be effective an effective pretreatment process for alternatives which employ ground-water extraction. However, this technology can be difficult to implement and costly for treating large volumes of water. Therefore, ion exchange will not be retained for further consideration.

2.7.5.4 *Ex-Situ* Treatment - Biological

Ex-situ bioremediation of ground water utilizes biological activity to break down organic compounds. Biological treatment can be conducted under aerobic or anaerobic conditions. Anaerobic biodegradation is more difficult than aerobic biodegradation due to the sensitivity and slower metabolism of the anaerobic bacterial species. *Ex-situ* bioremediation of ground water would require extraction from the subsurface using wells with subsequent onsite treatment using bioreactors or an activated sludge process. These treatment processes would generate sludge requiring disposal on a regular basis.

- **Effectiveness** - *Ex-situ*, anaerobic bioremediation may be able to degrade the organic COC identified in shallow, deep, and bedrock ground water. The use of anaerobic conditions in a bioreactor is primarily limited by the rate at which chlorinated VOC degrade and, therefore, may not an effective technology in treating large volumes of ground water. Co-metabolic degradation mechanism is being utilized in laboratory scale aerobic bioreactors for the degradation of chlorinated VOC with mixed results. Incomplete degradation of some chlorinated COC (e.g., PCA, TCE) may result in more toxic by-products (e.g., VC).

- **Implementability** - This technology can be implementable because the materials, equipment, and services are commercially available. Anaerobic systems, which may be required for the treatment of chlorinated organic compounds, are more difficult to implement then aerobic bioremediation systems due to the sensitivity of the bacterial population. Anaerobic systems are also less common than aerobic systems.

It is anticipated that *ex-situ* bioremediation techniques will not be effective for treating large amounts of ground water from Site 07 due to the low biodegradation rates of chlorinated VOC. Therefore, this technique will not be retained for further consideration.

2.7.6 Ground-Water Discharge Actions

Any *ex-situ*, ground-water remedial action would require a point of discharge for the treated ground water. The treated ground water on discharge must meet the concentrations requirements of a Rhode Island Pollutant Discharge Elimination System (RIPDES) permit. There are three discharge options for the treated ground water at the Site 07:

- Discharge to surface water (i.e., to Allen Harbor or Narragansett Bay),
- Discharge to the local Public Owned Treatment Works (POTW), and/or

- Recharge ground water through injection wells.

Any discharge method adopted would be subject to discharge standards and/or permits. One discharge option, or a combination of these options, may be selected.

Discharge to Surface Water

Under this option, treated ground water would be discharged into Allen Harbor or Narragansett Bay. Both the surface water bodies are located adjacent to Site 07. Ground water would likely have to meet state Class SA criteria or federal AWQC.

- **Effectiveness** - Discharging the treated water to the site surface water should be effective as long as the proposed cleanup levels are met.

- **Implementability** - Allen Harbor and Narragansett Bay are adjacent to Site 07, therefore, piping can be readily installed. However, meeting the requirements of a discharge permit for treated ground water may be difficult based upon the requirements of Section 7.4 of the Rhode Island Rules and Regulations for Water Pollution Control ("...no new discharges shall be permitted into Class A or SA waters...new discharges shall be construed to include potential direct discharges from POTWs, fixed privately owned treatment systems, industrial processes wastes, or wastes resulting from concentrations of vessels such as might be found in marinas....this subsection shall not apply to (1) discharges of normal storm water drainage; and (2) industrial non-contact cooling water...").

The discharge of treated ground water into surface water would be effective; however, state acceptance would be required. This option will be retained for further consideration.

Discharge to POTW

This option consists of discharging treated ground water to the RIEDC POTW.

- **Effectiveness** - This option would be effective for final disposal of the treated ground water from Site 07 provided the proposed cleanup levels are met.

- **Implementability** - This option may be implementable at Site 07; however, the nearest sewer main is located over one mile from Site 07.

Discharge to POTW may be an effective option for the discharge of treated ground water; however, some implementation difficulties may include piping to a distant location and obtaining a permit to discharge large volumes. This option will not be retained for further consideration.

Recharge Ground Water (Reinjection)

Recharging ground water refers to the use of a sandy structure which would enhance water infiltration into the ground-water aquifer or by pumping water into the aquifer directly. In general, there are two advantages by recharging the aquifer:

- disposal of treated ground water and
- preventing acute deterioration of the ground-water yield of the aquifer.

Treated ground water can be discharged to the aquifer through injection wells or infiltration trenches. The amounts that can be discharged depends on the subsurface characteristics at the site. Presence of high permeability media and high aquifer recharge are necessary for using this discharge option. The sizes of the infiltration trenches and the number of injection wells also depend upon these characteristics.

- **Effectiveness** - Infiltration trenches are very effective in sandy soil. Injection wells can be effective depending on the recharge volumes. Reinjection may not be effective in the deep aquifer at Site 07 due to the low permeability of the silt and lower sand/till units. Aquifer recharge tests would have to be performed to determine the location for effective recharge of ground water.

- **Implementability** - Reinjection wells may be implementable in the more permeable shallow ground-water zone but, in an administrative sense, obtaining permits for reinjection can be difficult.

Reinjection of treated ground water may have limited effectiveness due to the low permeability of most site soil. Obtaining permits for reinjection can be difficult. Because the aquifer at Site 07 is not used for domestic or industrial purposes, reinjection does not offer any advantages over other effective means for disposal of treated ground water (to POTW or surface water). Therefore, this option will not be retained for further consideration.

2.8 SUMMARY OF TECHNOLOGY SCREENING

Based on the screening of remedial technologies, certain technologies which are not effective or implementable for the affected media at Site 07 have been eliminated from further consideration. Some of the technologies which have been retained will be used as a resource to develop remedial action alternatives in Chapter 3. Table 2-10 summarizes the remedial technologies/approaches that have been retained at the conclusion of the technology screening.

3. DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

In this chapter, technologies which were retained from the initial screening (Chapter 2) are grouped into potential remedial action alternatives (Section 3.1). These alternatives are then screened based on effectiveness, implementability, and cost considerations (Section 3.2). The purpose of this screening is to identify the alternatives which will be retained for the Detailed Analysis of Alternatives presented in Chapters 4 and 5.

3.1 DEVELOPMENT OF REMEDIAL ALTERNATIVES

As outlined in Table 2-8, RAO and General Response Actions were developed to address the risks associated with human ingestion and use (showering) of deep and bedrock ground water and to address COC that exceed RIDEM's Method 1 Class GB criteria for site ground water. No soil source removal/containment/treatment alternatives were developed for Site 07 because neither remnants of past disposals (e.g., canisters of DANC solution) nor elevated concentrations of COC in soil have been identified during the Phase I, II, or III RI reports. Therefore, remedial alternatives for Site 07 were developed to address the risk pathways and PRG (performance standards) for COC in ground water.

Based upon the RAO, the following potential remedial alternatives were developed for Site 07 from the technologies which were retained from the preliminary screening in Chapter 2:

Alternative 1: No Action
Alternative 2: Deed Restriction and Long-Term Monitoring
Alternative 3: *In-Situ* Anaerobic Biodegradation
Alternative 4: Vacuum-Vaporizer Wells
Alternative 5: *In-Situ* Permeable Reaction Wall
Alternative 6: Ground-Water Extraction with *Ex-Situ* Air Stripping

To meet the RAO, each of the proposed remedial actions (with the exception of the No Action alternative) include deed restrictions prohibiting the future use of site ground water and a long-term monitoring to ensure that the site continues to pose no unacceptable risks. Because ground-water treatment technologies are included as part of Alternatives 3 through 6, these alternatives also include ground-water monitoring to evaluate the performance of these treatment processes.

Remedial Alternatives 1 through 6 are described in Sections 3.1.1 through 3.1.6 and are evaluated in Sections 3.2.1 through 3.2.6, respectively.

3.1.1 Alternative 1: No Action

The "No Action" alternative provides the baseline against which the other remedial alternatives will be compared. Under this alternative, no remedial actions or institutional controls would be implemented. Because no remedial actions would be initiated, no action-specific ARARs have been identified for this alternative. As required by CERCLA Section 121(c), 5-year reviews will be conducted because wastes would be left onsite above health-based levels. ARARs for Alternative 1 are presented in Table 3-1.

3.1.2 Alternative 2: Deed Restriction and Long-Term Monitoring

Alternative 2 will protect human health and the environment through the following remedial components:

- Deed restriction prohibiting the future use of site ground water;
- Long-term monitoring (to ensure that the plume continues to pose no unacceptable risks); and
- 5-year reviews.

The unacceptable risks to human health at Site 07 only include the ingestion and/or use (showering) of deep and bedrock ground water. No unacceptable ecological risks were identified at, or linked to, Site 07. Therefore, a deed restriction prohibiting the future use of site ground water will effectively address the risks at Site 07. The deed restriction would cover the areal extent of Site 07 (the portion of Calf Pasture Point south of the bedrock outcrop—as shown in Figure 1-4). ARARs for Alternative 2 are presented in Tables 3-2 and 3-3.

As required by CERCLA Section 121(c), 5-year reviews will be conducted because COC would be left onsite above the established health-based levels. A long-term monitoring program including selected upgradient, downgradient, and side-gradient wells will be conducted as part of Alternative 2. In addition, periodic inspections of the land use will be conducted to ensure that the deed restriction remains effective. The scope of the long-term monitoring program (e.g., specific well locations, sampling frequency, analytical parameters, exit criteria, action levels) is being developed in a Long-Term Risk Monitoring Plan for Site 07. The monitoring events will account for seasonal variations such as changes in the water table level. Upgradient wells (potentially MW07-22S/D) will be used to characterize ground water entering Site 07 (i.e., background wells) and to ensure that the COC plume is not migrating north toward offsite Class GA aquifers. Downgradient wells will focus on potential discharge areas (e.g., where the plume appears to be rising from the deep to the shallow aquifer). Side-gradient wells will be used to confirm that the plume will not significantly increase in lateral extent. As warranted, based upon trends observed from the ground-water data, the monitoring program could also include seep/sediment sampling from the shoreline and seep/sediment samples from the interior wetlands area. Samples collected during the monitoring program will be analyzed for the Site 07 COC. The overall long-term monitoring program will be flexible in scope to respond to trends observed in the ground-water COC data. If, during the review periods, future remedial action or additional monitoring should prove necessary, appropriate risk reduction measures can then be further evaluated.

3.1.3 Alternative 3: *In-Situ* Anaerobic Biodegradation

Alternative 3 is an innovative, *in-situ*, ground-water treatment remedial action which will protect human health and the environment through the following remedial components:

- Deed restriction prohibiting the future use of site ground water;
- Installation of injection wells which will be used to promote the anaerobic biodegradation of organic COC within portions of the plume;
- Long-term monitoring (to evaluate the effectiveness of assisted biodegradation and to ensure that the plume continues to pose no unacceptable risks); and
- 5-year reviews.

A conceptual diagram of this alternative is depicted in Figure 3-1. ARARs for this alternative are presented in Tables 3-4 and 3-5

This alternative provides for the treatment of VOC in shallow and deep ground water primarily in the vicinity of the ground-water source areas. Conceptually, five deep injection wells and two shallow injection wells would be installed in the vicinity of the two plumes (i.e., the deep plume below the DANC disposal area and the shallow plume around MW07-19S, respectively). An additional deep well would be installed in the southern portion of the site (near MW07-23D) in an area where high total chlorinated VOC also were detected. The two shallow wells would be installed into the upper sand unit and the deep wells would be installed in the lower sand/till unit. The well location points were selected based on the observed VOC concentrations in ground water, the ground-water flow direction, and the thickness of the till unit. The location for the wells in the northern region of the site were selected based on where the thickness of the till unit is greater than 5 ft. The hydraulic conductivity in the region is low; therefore, if the injection wells operate in an interval of the till unit of less than 5 ft, then there could be an upward gradient of the deep aquifer which potentially could force the migration of COC from the till into the silt or the upper sand. Injection well locations and pumping rates are intended to prevent this from occurring.

For 8 hours per day, each of the injection wells would be used to inject approximately 2 to 5 gallons per minute (gpm) of a suitable aqueous substrate (carbon source) within or upgradient of ground-water source areas. Above-ground components would include feed tanks, pumps, piping, and electrical control systems. Injection of the substrate will promote the anaerobic biodegradation of chlorinated VOC in ground water. Other demonstration sites have indicated that, with the addition of this food source (such as acetate or sodium benzoate solutions), intrinsic microorganisms will increase the consumption of dissolved oxygen and will then, under the generated anaerobic conditions, begin to use the chlorinated organic compounds as an oxygen substitute. An initial estimate of the substrate requirement is assumed to be a substrate-to-COC ratio of 50 lb/lb, by weight. Based upon the results of a treatability study, this ratio will likely be refined to account for the actual density of intrinsic bacteria. As the density of bacteria increases over time, the substrate-to-COC ratio would be decreased. Approximately half of the substrate solution will consist of nutrients.

A treatability study and a tracer study would be conducted to confirm and optimize the effectiveness of this process, to investigate the area of influence, and to identify the type and density of bacteria present in the subsurface at Site 07. Also, the maximum degradation rates of chlorinated VOC that can be obtained using the bacteria will be evaluated. Once operational, it is estimated that a full-scale system would run for approximately two years to inject this initial mass of substrate to begin reducing COC concentrations in shallow and deep ground-water source areas. Ground-water monitoring during and after that time would be used to determine the amount of additional substrate injection that is warranted (i.e., the ground-water plume would not be remediated within the two years that the initial substrate mass is injected).

Initially, the anaerobic zone would be maintained to degrade the higher chlorinated COC. Upon the degradation of these compounds to lesser chlorinated VOC, an aerobic environment would be provided to further degrade the lesser chlorinated VOC into innocuous degradation products. During operation of the injection system, ground-water monitoring will be performed to evaluate the biodegradation of the chlorinated VOC.

Installing injection wells in bedrock ground water may not be feasible due to the difficulties in effectively locating bedrock fractures and overcoming mass transfer limitations therein (i.e., it would be unlikely that the injection wells could evenly distribute the injected solution throughout affected regions of the bedrock). However, the risks associated with the elevated levels of COC in bedrock ground water and areas of the plume outside the treatment zone would be addressed through the deed restriction.

As required by CERCLA Section 121(c), 5-year reviews will be conducted because COC would be left onsite above the established health-based levels. A long-term monitoring program including selected upgradient, downgradient, and side-gradient wells will be conducted as part of Alternative 3. In addition, periodic inspections of the land use will be conducted to ensure that the deed restriction remains effective. The scope of the long-term monitoring program (e.g., specific well locations, sampling frequency, analytical parameters, exit criteria, action levels) is being developed in a Long-Term Risk Monitoring Plan for Site 07. The monitoring events will account for seasonal variations such as changes in the water table level. Upgradient wells (potentially MW07-22S/D) will be used to characterize ground water entering Site 07 (i.e., background wells) and to ensure that the COC plume is not migrating north toward offsite Class GA aquifers. Downgradient wells will focus on potential discharge areas (e.g., where the plume appears to be rising from the deep to the shallow aquifer). Side-gradient wells will be used to confirm that the plume will not significantly increase in lateral extent. As warranted, based upon trends observed from the ground-water data, the monitoring program could also include seep/sediment sampling from the shoreline and seep/sediment samples from the interior wetlands area. Samples collected program will be analyzed for the Site 07 COC. The overall long-term monitoring program will be flexible in scope to respond to trends observed in the ground-water COC data. If, during the review periods, future remedial action or additional monitoring should prove necessary, appropriate risk reduction measures can then be further evaluated. As feasible to avoid redundancies, monitoring for treatment system performance will be conducted in conjunction with monitoring of the plume.

3.1.4 Alternative 4: Vacuum-Vaporizer Wells

Alternative 4 is an innovative technology which involves *in-situ* ground-water treatment. This alternative will protect human health and the environment through the following remedial components:

- Deed restriction prohibiting the future use of site ground water;
- Installation and operation of Vacuum-Vaporizer Wells to treat ground-water source areas;
- Treatment of offgas from Vacuum-Vaporizer Wells;
- Long-term monitoring (to evaluate the effectiveness of the Vacuum-Vaporizer Well system and to ensure that the plume continues to pose no unacceptable risks); and
- 5-year reviews.

Conceptual diagrams of Alternative 4 are presented in Figures 3-2 through 3-4. ARARs for this alternative are presented in Tables 3-6 and 3-7

This alternative provides for treatment of VOC in shallow and deep ground water at the sources of the two plumes. Conceptually, three Vacuum-Vaporizer-Wells would be installed in the vicinity of the DANC disposal area within the lower sand/till unit. In addition, one Vacuum-Vaporizer-Well would be installed in the southern portion of the site near MW07-19S.

The dual-screen, Vacuum-Vaporizer Wells would operate by drawing in ground water from the lower screened interval along with introduced atmospheric air. Within the stripping zone of the well, VOC from this ground water would partition into the air within the well. The offgas air from the wells would be manifolded into a central, GAC system located on the ground surface prior to discharge to the atmosphere. The treated ground water would re-enter the aquifer through the upper screened interval of the well. The wells would be installed so that the upper screens are not located within the silt unit (so that discharge of treated ground water would not be restricted). Also, the well placement would be controlled such that the two screened intervals of the Vacuum-Vaporizer Wells do not straddle the silt unit (in order to maintain a zone of circulation between the two screened intervals for the ground water within the radius of influence for the well). Additional components for the Vacuum-Vaporizer Well and offgas treatment systems include blowers, air/water separators, manifold piping, valves, and electrical system controls.

The types of Vacuum-Vaporizer Wells would be selected to obtain the maximum radius of influence near the source areas. In general, the radius of influence for this technology is highly dependent on site geology (e.g., horizontal vs. vertical hydraulic conductivities, thickness of the geological units, as well as well specifications such as screen length and spacing); therefore, a pilot study would be performed to determine and optimize the effectiveness of this technology at Site 07. Other demonstration sites/models have indicated a wide range of treatment radii between 35 and 80 ft per well. However, because the thickness of the till unit is small in the vicinity of the higher total chlorinated VOC concentrations (i.e., the 100,000 μg/L contour shown in Figure 1-20) and due to the presence of silt unit above the till unit, the radius of influence that can be obtained in the source area may be at the lower end of this range. Therefore, the proposed Vacuum-Vaporizer Well locations were chosen to be slightly north and south of the source area where the till unit is thicker and the distance between the screens is sufficient to obtain larger radius of influence. Based upon the site-specific subsurface data, a vendor estimated radius of influence of 35 ft was obtained for the deep aquifer.

Monitoring of the system offgas would be performed to determine whether GAC treatment would be required. Ground-water monitoring would be performed to evaluate system performance.

A treatability study would be performed to predict system performance and to optimize the design (e.g., well locations to maximize radius of influence, well materials to account for potential ground-water corrosivity) and operation (e.g., air flow rates, air temperature compensations) of the system.

The Vacuum-Vaporizer-Well system would not treat the entire plume or bedrock ground water; however, the risks associated with the elevated levels of COC in these areas would be addressed through the deed restriction.

As required by CERCLA Section 121(c), 5-year reviews will be conducted because COC would be left onsite above the established health-based levels. A long-term monitoring program including selected upgradient, downgradient, and side-gradient wells will be conducted as part of Alternative 4. In addition, periodic inspections of the land use will be conducted to ensure that the deed restriction remains effective. The scope of the long-term monitoring program (e.g., specific well locations, sampling frequency, analytical parameters, exit criteria, action levels) is being developed in a Long-Term Risk Monitoring Plan for Site 07. The monitoring events will account for seasonal variations such as changes in the water table level. Upgradient wells (potentially MW07-22S/D) will be used to characterize ground water entering Site 07 (i.e., background wells) and to ensure that the COC plume is not migrating north toward offsite Class GA aquifers. Downgradient wells will focus on potential discharge areas (e.g., where the plume appears to be rising from the deep to the shallow aquifer). Side-gradient wells will be used to confirm that the plume will not significantly increase in lateral extent. As warranted based upon trends observed from the ground-water data, the monitoring program could also include seep/sediment sampling from the shoreline and seep/sediment samples from the interior wetlands area. Samples collected during the monitoring program will be analyzed for the Site 07 COC. The overall long-term monitoring program will be flexible in scope to respond to trends observed in the ground-water COC data. If, during the review periods, future remedial action or additional monitoring should prove necessary, appropriate risk reduction measures can then be further evaluated. As feasible to avoid redundancies, monitoring for treatment system performance will be conducted in conjunction with monitoring of the plume.

3.1.5 Alternative 5: *In-Situ* Permeable Reaction Wall

Alternative 5 is an innovative technology which involves the *in-situ* treatment of shallow and deep ground water exiting Site 07. This alternative will protect human health and the environment through the following remedial components:

- Deed restriction prohibiting the future use of site ground water;
- Installation of an *in-situ* treatment system which channels (via sheet pile walls) affected shallow and deep ground water through a permeable, reactive wall that will promote the degradation of chlorinated COC;
- Long-term monitoring (to evaluate the effectiveness of the *In-Situ* Permeable Reaction Wall system for reducing chlorinated COC concentrations migrating offsite via shallow/deep ground water and to ensure that the plume continues to pose no unacceptable risks); and
- 5-year reviews.

Conceptual diagrams of Alternative 5 are presented in Figures 3-5 and 3-6. ARARs for this alternative are presented in Tables 3-8 and 3-9.

This alternative provides for treatment of VOC in shallow and deep ground water as it exits the site (rather than within the shallow and deep ground-water source areas). Conceptually, approximately 1,700 linear ft of sheet pile wall would be installed down to the bedrock surface on the eastern and western sides of the plumes in order to channel the two VOC plumes through a permeable, *in-situ*, reactive wall located along the southern shoreline. This treatment zone would be constructed with a sheet pile wall containing four intermittent permeable treatment sections (containing iron-based catalysts) each measuring approximately 50 ft in length. The reaction wall would be approximately 200 ft long × 4 ft wide × 35 ft deep (note: with the intermittent sheet pile, the total length of the wall along the southern shoreline would be approximately 500 ft—Figure 3-5). The iron-based catalyst would promote the degradation of halogenated compounds by abiotic or biological processes as they pass through the wall (i.e., the system induces conditions where halogen atoms are replaced by hydrogen atoms). Remediated ground water would exit the downgradient side of the permeable reaction wall. The treatment sections of the reaction wall would be replaced/maintained, as required, in order to replenish the iron-based catalyst.

A bench-scale treatability study would be performed to develop the proper catalyst/soil mixture as well as the thickness of the wall for the full-scale system. Here, a sample of ground water from the site (representative of the higher COC concentrations) would be pumped through a horizontal column containing the permeable reactive media. Influent and effluent COC concentrations would be compared to evaluate the degradation rates for the COC through the media. Iron content of the test media can be varied to optimize the process. Based upon these degradation rates, the required retention time to achieve performance standards can be determined (and accordingly, the required width of the full-scale permeable reaction wall). A reaction wall of 4 ft thick is assumed at this time, based upon vendor estimates. In addition, the treatment portion of the system is currently estimated to consist of four permeable reaction walls (50 ft long and 35 ft deep); sheet pile walls connect each of these permeable reaction zones. The permeable reaction (containing the iron-based catalyst) would be installed by using either trench boxes or caissons. The performance of the reaction wall could be affected by the precipitation of carbonates from ground water. Occasional mixing of the iron filings in the reaction wall, as necessary, would reduce the affect of precipitation on the reaction wall performance.

Performance of this system would be evaluated using several piezometers and selected monitoring wells. Piezometers would be placed on either side of the sheet pile walls at selected locations to evaluate the effectiveness for controlling shallow and deep ground-water flow (e.g., by monitoring differences in water elevations and/or selected COC concentrations across the sheet pile walls). Selected monitoring wells located downgradient of the sheet pile walls would also be sampled for selected COC. Three additional shallow and four additional deep monitoring wells would be installed on the downgradient (shoreline) side of the reaction wall (Figure 3-5) in order to evaluate the effectiveness for reducing COC concentrations. Although side-gradient bedrock monitoring wells will be used (because this system will not control bedrock ground-water flow), side-gradient shallow and deep monitoring wells will not be required because the sheet pile walls will control ground-water flow above bedrock. Side-gradient piezometers will be used to evaluate the effectiveness of the sheet pile walls.

This alternative will not treat some COC (arsenic, benzene, and 1,2-DCA), bedrock ground water, or shallow/deep ground-water source areas; however, the associated risks would be addressed through the deed restriction.

As required by CERCLA Section 121(c), 5-year reviews will be conducted because COC will be left onsite above the established health-based levels. A long-term monitoring program will also be conducted as part of Alternative 5. This long-term monitoring program will be similar to those specified under Alternatives 2 through 4; however, there will be some modifications in order to avoid redundancies with the performance evaluation monitoring program. In addition, periodic inspections of the land use will be conducted to ensure that the deed restriction remains effective. The scope of the long-term monitoring program (e.g., specific well locations, sampling frequency, analytical parameters, exit criteria, action levels) is being developed in a Long-Term Risk Monitoring Plan for Site 07. The monitoring events will account for seasonal variations such as changes in the water table level. Upgradient wells (potentially MW07-22S/D) will be used to characterize ground water entering Site 07 (i.e., background wells) and to ensure that the COC plume is not migrating north toward offsite Class GA aquifers. As warranted based upon trends observed from the ground-water data, the monitoring program could also include seep/sediment sampling from the shoreline and seep/sediment samples from the interior wetlands area. Samples collected during the monitoring program will be analyzed for the Site 07 COC. The overall long-term monitoring program will be flexible in scope to respond to trends observed in the ground-water COC data. If, during the review periods, future remedial action or additional monitoring should prove necessary, appropriate risk reduction measures can then be further evaluated.

3.1.6 Alternative 6: Ground-Water Extraction with *Ex-Situ* Air Stripping

Alternative 6 is a "pump-and-treat" option which will protect human health and the environment through the following remedial components:

- Deed restriction prohibiting the future use of site ground water;
- Installation of ground-water extraction systems within the source areas of the two ground-water plumes;
- Installation of manifold piping to carry extracted ground water into a central, onsite, treatment system;
- Treatment of ground water with a series of onsite unit processes consisting of pre-treatment to remove particulates and dissolved metals (conventional filtration, coagulation, flocculation, sedimentation) and air stripping to remove VOC (with offgas treatment);
- Discharge of treated ground water to Narragansett Bay;
- Long-term monitoring (to evaluate the effectiveness of the pump-and-treat system and to ensure that the plume continues to pose no unacceptable risks); and
- 5-year reviews.

Conceptual diagrams of Alternative 6 are presented in Figures 3-7 and 3-8. ARARs for this alternative are presented in Tables 3-10 and 3-11

This pump-and-treat alternative provides for the *ex-situ* treatment of affected ground water from the vicinity of the source areas. Conceptually, three extraction wells would be installed into the deep aquifer in the vicinity (slightly downgradient) of the DANC disposal area and two extraction wells would be installed into the shallow aquifer within the second plume at MW07-19S and MW07-21S. The deep wells would be screened within the lower sand/till unit and the shallow wells would be screened within the upper sand unit. Ground water would be extracted at a low flow-rate because (1) the hydraulic conductivity of the deep aquifer is low, (2) a low flow-rate would reduce salt water migration toward the deep VOC plume (the salt content of the extracted ground water may complicate the operation of the *ex-situ* ground-water treatment processes), and (3) high rate pumping near MW07-21S would likely bring in harbor water which would create additional costs through the unnecessary treatment and/or conveyance of additional volumes of clean salt water.

The WHPA model (developed for the EPA for the well head protection program) was used to provide an estimate of the pumping rates and zone of influence of the extraction wells located in the deep aquifer and the shallow aquifer (Appendix A). For the deep plume in the vicinity of the DANC disposal area, it was estimated from the model that the deep extraction wells each pumping at a rate of 5 gpm would provide effective capture of VOC out to the 10,000 μg/L total chlorinated VOC contour (Figure 1-20) without significantly pulling in brackish water into the extraction system (a high salinity may disrupt *ex-situ* treatment processes such as chemical precipitation and potentially air stripping; a high salinity may also shorten the effective life of GAC). Based upon information contained in the previous RI reports, these pumping rates and effective capture zones were determined using a hydraulic conductivity of 30 ft/day, a transmissivity of 150 ft^2/day, a saturated thickness of till unit of 5 ft, and a porosity of 30%. The two proposed shallow extraction wells are located slightly upgradient of MW07-19D and MW07-21R. Using an hydraulic conductivity of 133.3 ft/day, a transmissivity of 2332.8 ft^2/day, a saturated thickness of the till unit of 17.5 ft, and a porosity of 30%, it was estimated from the model (Appendix A) that shallow extraction wells each pumping at a rate of 10 gpm would address the western portion of the 10 μg/L total chlorinated VOC contour (Figure 1-19) along with the source area without significantly pulling in brackish water into the extraction system.

A manifolded piping system would be constructed to transport the extracted ground water to a central, onsite treatment system. The *ex-situ* ground-water treatment system would consist of a multi-stage process including pre-treatment, air stripping, and effluent treatment/disposal. Pre-treatment (filtration, coagulation, flocculation, sedimentation) would be required to remove particulates and dissolved metals which may reduce the effectiveness of air stripping. Removal of particulates can be accomplished through conventional filtration and/or sedimentation processes. Most metal COC can be removed through conventional coagulation, flocculation, and sedimentation processes. Air stripping would be used to transfer VOC from ground water to air through a counter-current flow packed tower. Extracted ground water would be pumped to the top of the air stripping tower where it will cascade over a densely-packed media with a high surface area-to-volume ratio. VOC with a Henry's Law constant greater than 10^5 atm-m^3/mol will readily transfer to the air stream being pumped up through the tower (Brown et al., 1991 and Lyman and Rosenblatt, 1992). The counter-current flow of the air stream will enhance the volatilization of VOC.

Treated ground water will be collected from the bottom of the tower, passed through a final-stage (polishing) GAC canister and discharged to Narragansett Bay. Periodic monitoring of the effluent will be required to ensure that the discharge meets the substantive requirements of a RIPDES permit. Ground-water monitoring would be performed to evaluate system effectiveness. The effluent air from the unit will pass through a vapor-phase GAC canister prior to discharge to the atmosphere, as necessary.

Alternative 6 would treat ground-water source areas. This alternative would not treat downgradient portions of the plume or bedrock ground water; however, the risks associated with the elevated levels of COC in these areas would be addressed through the deed restriction.

As required by CERCLA Section 121(c), 5-year reviews will be conducted because COC would be left onsite above the established health-based levels. A long-term monitoring program including selected upgradient, downgradient, and side-gradient wells will be conducted as part of Alternative 6. In addition, periodic inspections of the land use will be conducted to ensure that the deed restriction remains effective. The scope of the long-term monitoring program (e.g., specific well locations, sampling frequency, analytical parameters, exit criteria, action levels) is being developed in a Long-Term Risk Monitoring Plan for Site 07. The monitoring events will account for seasonal variations such as changes in the water table level. Upgradient wells (potentially MW07-22S/D) will be used to characterize ground water entering Site 07 (i.e., background wells) and to ensure that the COC plume is not migrating north toward offsite Class GA aquifers. Downgradient wells will focus on potential discharge areas (e.g., where the plume appears to be rising from the deep to the shallow aquifer). Side-gradient wells will be used to confirm that the plume will not significantly increase in lateral extent. As warranted based upon trends observed from the ground-water data, the monitoring program may also include seep/sediment sampling from the shoreline and seep/sediment samples from the interior wetlands area. Samples collected during the monitoring program will be analyzed for the Site 07 COC. The overall long-term monitoring program will be flexible in scope to respond to trends observed in the ground-water COC data. If, during the review periods, future remedial action or additional monitoring should prove necessary, appropriate risk reduction measures can then be further evaluated. As feasible to avoid redundancies, monitoring for treatment system performance will be conducted in conjunction with monitoring of the plume.

3.2 SCREENING OF REMEDIAL ALTERNATIVES

In this section, the alternatives which were developed in Section 3.1 are evaluated with respect to effectiveness, implementability, and cost in accordance with the NCP. The evaluation for effectiveness includes the short-term and long-term effectiveness and the reduction of toxicity, mobility, and/or volume of COC. The evaluation of implementability addresses the technical concerns (e.g., ability to construct, operate, and maintain the remedial components) and administrative concerns (e.g., coordination with regulatory agencies, offsite or onsite disposal considerations, the need for specialists or skilled operators). The cost evaluation includes capital costs and annual operation and maintenance (O&M) costs. Present worth costs are based on a 30-year period, a 5% discount rate, and 1998 dollars. The costs presented in this section are provided to allow comparisons of the order of magnitude of costs associated with the remedial alternatives.

3.2.1 Alternative 1: No Action

3.2.1.1 Effectiveness

Alternative 1 would not be effective for addressing site risks because it provides no remedial actions or institutional controls. The No Action alternative would not manage site risks in the short- or long-term and, therefore, would not meet RAO. No treatment would be specified to reduce the toxicity, volume, or mobility of COC at the site; however, no new risks to site workers or the community would be created through implementation of the No Action alternative.

3.2.1.2 Implementability

The No Action alternative would be readily implementable in a technical sense because no remedial efforts would be required other than a periodic review of the No Action decision. However, this alternative would not be implementable in an administrative sense because the identified unacceptable risks at the site would not be managed.

3.2.1.3 Cost

The costs associated with the No Action alternative only include the nominal costs of conducting 5-year reviews of the No Action decision.

Capital Cost =	none
Annual O&M Cost =	nominal
Total 30-year Present Worth =	nominal

3.2.1.4 Conclusions

Because no remedial components would be specified for addressing site risks, the No Action alternative would not be effective or implementable for addressing the unacceptable risks at Site 07. However, the NCP requires that the No Action alternative to be retained as a baseline comparison for the other remedial alternatives; therefore, Alternative 1 will be retained for the Detailed Analysis in Chapter 4.

3.2.2 Alternative 2: Deed Restriction and Long-Term Monitoring

3.2.2.1 Effectiveness

The unacceptable risks identified at Site 07 are for the ingestion and use (showering) of deep and/or bedrock ground water. Alternative 2 will be effective for addressing the short-term and long-term risks by implementing a deed restriction prohibiting the future use of site ground water (an institutional control). No treatment would be conducted to reduce the toxicity, mobility, or volume of COC in site ground water; however, the risks associated with the elevated levels of COC at the site would be effectively addressed through the deed restriction. Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely become a source for drinking water or for showering facilities in the future (1) due to its high salinity, (2) because public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations. The 5-year reviews and the long-term monitoring program will be effective in the long-term for evaluating the Alternative 2 decision.

3.2.2.2 Implementability

Alternative 2 is implementable at Site 07. The technical and administrative implementation requirements would consist of creating a deed restriction prohibiting the future use of site ground water and conducting periodic reviews. Conducting a long-term monitoring program will be readily implementable because the existing monitoring well network can be used or readily modified. Although this alternative would not reduce COC levels through treatment, the identified risks to human health (from the hypothetical exposure scenarios of ingestion and use of deep and bedrock ground water) would be adequately addressed. Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely become a source for drinking water or for showering facilities in the future (1) due to its high salinity, (2) because public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations. Treatment may also not be warranted or practicable because (1) the identified unacceptable risks to human health can be addressed through a deed restriction, (2) no significant onsite ecological risks were identified, (3) no site-related COC have been identified in downgradient environmental media (shoreline sediment or shellfish), and (4) locating and treating COC contained in bedrock fractures and potential residual DNAPL contained in soil void spaces at the source can be technically impracticable.

3.2.2.3 Cost

The costs associated with Alternative 2 include implementing a deed restriction and long-term monitoring.

Capital Cost =	$ 130,000
Annual O&M Cost =	$ 247,000
Total 30-year Present Worth =	$ 1,679,000

3.2.2.4 Conclusions

Alternative 2 will be effective and implementable for addressing the site risks. Based upon the HHRA, the Freshwater/Terrestrial ERA, and the Marine ERA, the only unacceptable risks at Site 07 are associated with the human consumption and use (showering) of deep and bedrock ground water. The deed restriction implemented under Alternative 2 will be effective for addressing these risks. Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely become a source for drinking water in the future (1) due to its high salinity, (2) due to the availability of public water in the area, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations. Alternative 2 does not include treatment for ground-water COC which exceed RIDEM's Method 1 Class GB ground-water objectives; however, the deed restriction will address the risks associated with these elevated COC as identified during the HHRA (note: the HHRA performed during the Phase III RI is indicative of a site-specific Method 3 assessment allowable by RIDEM for the determination of remedial goals). Therefore, the Deed Restriction and Long-Term Monitoring alternative will be retained for the Detailed Analysis in Chapter 4.

3.2.3 Alternative 3: *In-Situ* Anaerobic Biodegradation

3.2.3.1 Effectiveness

The unacceptable risks identified at Site 07 are for the ingestion and use (showering) of deep and/or bedrock ground water. Alternative 3 will be effective for addressing the short-term and long-term risks by implementing a deed restriction prohibiting the future use of site ground water (an institutional control). Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely become a source for drinking water or for showering facilities in the future (1) due to its high salinity, (2) because public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations.

In-Situ Anaerobic Biodegradation is still an innovative/emerging technology and its effectiveness has not been proven. A treatability study would be performed at Site 07 in order to determine the effectiveness of this technology under site-specific conditions and for the Site 07 COC (e.g., types and concentrations of chlorinated VOC, presence of potentially inhibiting metals). Demonstration studies with similar applications of this form of biodegradation have suggested that chlorinated-COC can be effectively mitigated in ground water. Depending upon its application at Site 07, this technology may be able to reduce the toxicity, mobility, and volume of COC in shallow and deep ground water. A possible exception to the reduction of toxicity may be through the incomplete degradation of DCE to VC (a more toxic compound). Complete biodegradation would result in degradation of the organic COC to carbon dioxide, water, innocuous salts, and biomass (i.e., bacteria). A possible exception for the reduction of mobility may be associated with the partial biodegradation by-products of some VOC which have higher mobility in ground water (e.g., trans-1,2-DCE has a higher mobility than TCE as evidenced by its lower K_{oc} value). A monitoring program will be effective for evaluating the performance of this remedial alternative.

Alternative 3 will focus on treating ground-water source areas. This technology will likely have limited effectiveness for treating in bedrock ground water due to the potential mass transfer difficulties associated with placing/operating injection wells in fractured bedrock. The unacceptable risks associated with the elevated levels of COC in downgradient and bedrock portions of the plume would be effectively addressed through the deed restriction and the long-term monitoring program.

3.2.3.2 Implementability

Conducting *in-situ* anaerobic biodegradation may be implementable at Site 07 but with some design and operation difficulties. Conducting a long-term monitoring program will be readily implementable because the existing monitoring well network can be used or readily modified. A treatability study designed to examine the effectiveness of *in-situ* anaerobic biodegradation can be implementable; however, interpretation of the results can be difficult [e.g., differentiating between biodegradation and natural fluctuations in the monitoring program, determining the optimal organic source type and mass injection rate, promoting the growth of anaerobic bacteria (which have slower metabolisms than aerobic bacteria)]. Operation and design difficulties for the full-scale process include providing skilled operators, maintaining a strong anaerobic bacterial population over time, and optimizing the proper injection well positions (lateral distribution and depth of screening) and flow rates such that mass transfer limitations do not hinder the anaerobic biodegradation process. Mass transfer limitations typically are the primary limiting factor for operation of an *in-situ* bioremediation system. Administratively, some reluctance may be encountered because the effectiveness of this innovative technology has not been proven; however, a successful treatability study would address such concerns.

3.2.3.3 Cost

The costs associated with Alternative 3 include conducting a treatability study, constructing and operating the full-scale system (installing injection wells, purchasing pumps and stock solutions, wages for skilled operators), and conducting a long-term monitoring program.

Capital Cost =	$ 1,000,000
Annual O&M Cost =	$ 468,000
Total 30-year Present Worth =	$ 3,619,000

3.2.3.4 Conclusions

Although potentially difficult to implement, Alternative 3 may be effective for addressing the risks and RAO identified at Site 07. A treatability study would be required to determine the effectiveness and implementability of this innovative alternative. Alternative 3 may provide a means to destroy COC in shallow and deep ground-water source areas (rather than transferring COC to another media requiring treatment and/or disposal) utilizing natural, *in-situ* biological processes. The deed restriction will be effective for addressing site risks, including areas outside of the treatment zone. Therefore, Alternative 3 will be retained for the Detailed Analysis in Chapter 4.

3.2.4 Alternative 4: Vacuum-Vaporizer Wells

3.2.4.1 Effectiveness

The unacceptable risks identified at Site 07 are for the ingestion and use (showering) of deep and/or bedrock ground water. Alternative 4 will be effective for addressing the short-term and long-term risks by implementing a deed restriction prohibiting the future use of site ground water (an institutional control). Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely become a source for drinking water or for showering facilities in the future (1) due to its high salinity, (2) because public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations.

Vacuum-Vaporizer Wells are still an innovative/emerging technology but various demonstration sites have indicated its potential effectiveness for removing VOC from ground water. A pilot study (e.g., operation of one test well at the site) would be performed to predict system performance and to optimize the design (e.g., well locations to maximize radius of influence, well materials to account for potential ground-water corrosivity) and operation (e.g., air flow rates, air temperature compensations) of the system. If effective at Site 07, Vacuum-Vaporizer Wells would reduce the migration and volume of COC in shallow and deep ground water source areas. An *ex-situ*, vapor-phase GAC unit will be effective for removing VOC from the offgas of the system prior to discharging to the atmosphere. A long-term monitoring program will be effective for evaluating the performance of this remedial alternative.

Vacuum-Vaporizer Wells will likely have limited effectiveness for treating bedrock ground water due to the technical difficulties for implementing remediation within bedrock fractures. Furthermore, this is a ground-water source area treatment alternative and will not treat downgradient portions of the shallow/deep plume. However, the unacceptable risks associated with the elevated levels of COC in these areas will be adequately addressed through the deed restriction.

3.2.4.2 Implementability

In a technical sense, Alternative 4 appears to be implementable with some design difficulties. A long-term monitoring program will be readily implementable because the existing monitoring well network could be used or modified. A pilot study designed to examine the effectiveness of Vacuum-Vaporizer Wells can be implementable; however, interpretation of the results can be difficult. Operation and design difficulties for the full-scale process include determining proper well locations (lateral distribution and depth of screening) and flow rates. Vacuum-Vaporizer Wells can not be located in areas with a pronounced silt unit (i.e., a sufficient till and/or sand layer must be present). Administratively, some reluctance may be encountered because this is an innovative technology; however, a successful pilot study would address such concerns.

3.2.4.3 Cost

The costs associated with Alternative 4 include conducting a pilot study, constructing and operating the full-scale system (installing Vacuum-Vaporizer Wells manifolded into a central offgas treatment system), and conducting a long-term monitoring program.

Capital Cost =	\$ 1,383,000
Annual O&M Cost =	\$ 468,000
Total 30-year Present Worth =	\$ 5,867,000

3.2.4.4 Conclusions

Alternative 4 would be effective for addressing the site risks and RAO. A pilot study would be required to ensure its effectiveness under site-specific conditions; however, in general, Vacuum-Vaporizer Wells may be effective for reducing VOC concentrations in ground-water source areas. The deed restriction will be effective for addressing site risks, including areas outside of the treatment zone. Therefore, Alternative 4 will be retained for Detailed Analysis in Chapter 4.

3.2.5 Alternative 5: *In-Situ* Permeable Reaction Wall

3.2.5.1 Effectiveness

The unacceptable risks identified at Site 07 are for the ingestion and use (showering) of deep and/or bedrock ground water. Alternative 5 will be effective for addressing the short-term and long-term risks by implementing a deed restriction prohibiting the future use of site ground water (an institutional control). Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely become a source for drinking water or for showering facilities in the future (1) due to its high salinity, (2) because public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations.

An *In-Situ* Permeable Reaction Wall system is an innovative/emerging technology which may be effective for degrading most VOC in shallow and deep ground water leaving Site 07 (benzene and 1,2-DCA would not be treatable by this technology; however, these compounds were detected infrequently and are not the primary risk-drivers at Site 07—arsenic would also not be treated by this system). VOC concentrations in shallow and deep ground water would be reduced *in-situ* before migrating from the site. A treatability study would be required as part of the design process. A monitoring program will be effective for evaluating the performance of this remedial alternative.

An *In-Situ* Permeable Reaction Wall system would not treat ground-water source areas or bedrock ground water; however, the risks associated with the elevated levels of COC in these areas would be addressed through the deed restriction.

A treatability study would be performed in order to optimize the design of the *In-Situ* Permeable Reaction Wall system. The design (e.g., catalyst composition, wall thickness, maintenance frequency) would account for the types of COC to be treated as well as the Site 07 environment (e.g., ground-water salinity, temperature). These systems have been found to be effective in cold-temperature regions.

3.2.5.2 Implementability

In a technical sense, installation of an *In-Situ* Permeable Reaction Wall system and conducting a long-term monitoring program appears to be implementable. A long-term monitoring program will be readily implementable because the existing monitoring well network could be used or modified. A bench-scale treatability study can be implementable; however, translating laboratory results to a full-scale system can be difficult. Design and installation difficulties for the full-scale process include determining the proper catalyst mixture, driving extensive lengths of sheet pile down to an uneven bedrock topography, installing a trench along a shoreline, and performing periodic maintenance/replacement of the permeable, reactive zones.

3.2.5.3 Cost

The costs associated with Alternative 5 include conducting a treatability study, constructing the full-scale system (installing sheet pile walls, preparing the treatment zone), and conducting a long-term monitoring program.

Capital Cost =	$ 6,285,000
Annual O&M Cost =	$ 357,000[1]
Total 30-year Present Worth =	$ 9,062,000

3.2.5.4 Conclusions

Alternative 5 would be effective and implementable for addressing the site risks and RAO although a treatability study would be required to ensure its effectiveness under site-specific conditions. Therefore, Alternative 5 will be retained for Detailed Analysis in Chapter 4.

3.2.6 Alternative 6: Ground-Water Extraction with *Ex-Situ* Air Stripping

3.2.6.1 Effectiveness

The unacceptable risks identified at Site 07 are for the ingestion and use (showering) of deep and/or bedrock ground water. Alternative 6 will be effective in the short- and long-term for addressing these risks by implementing a deed restriction prohibiting the future use of site ground water (an institutional control). Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely become a source for drinking water or for showering facilities in the future (1) due to its high salinity, (2) because public water service is currently available to the adjacent community to the north of Calf Pasture Point, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations.

In the short-term, Alternative 6 would help to reduce COC concentrations within the shallow and deep ground-water source areas and to control the migration of the COC plume in shallow and deep ground water; however, pump-and-treat technologies are typically not effective in the long-term. Ground-water flow regimes are often complicated due to heterogeneous soil matrices; pockets of COC (or residual DNAPL potentially at the site) are often missed and remediation is often typified by an asymptotic COC removal rate. Such a decreasing removal rate will likely result in an impractical time-to-achieve remedial goals. The high expenses and continual level of effort for the long-term operation of a pump-and-treat system often are not justified by the diminishing effectiveness over time.

Ground-water extraction is not anticipated to be effective in bedrock due to the technical inability to intercept ground-water flow through bedrock fractures. Furthermore, it is difficult and costly to evaluate the lateral and vertical distribution of VOC in bedrock ground water and such data can often be inconclusive. A long-term monitoring program will be effective for evaluating the performance of this remedial alternative.

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[1] In addition to monitoring costs, the annual O&M cost estimate is based upon a periodic (e.g., once every five years) cost for maintenance and/or replacement of the reactive wall.

An air stripping tower (with pretreatment processes) would be effective for removing VOC from extracted ground water. The ground-water COC are volatile and would readily partition from ground water to the counter-current air flow within the air stripping tower. GAC would be effective for treating the offgas of the tower and as a final "polishing" step for the treated ground water. Pumping rates would have to be kept low in order to minimize difficulties in treating brackish or saline water. A high salt content may adversely affect some pretreatment processes as well as potentially air stripping and GAC adsorption. Pretreatment to reduce salinity in ground water would likely be cost-prohibitive (e.g., incorporating a RO unit in the pretreatment process).

Alternative 6 may be effective to treat the shallow and deep ground-water source areas. This alternative would not be effective for treated bedrock ground water or downgradient portions of the plume in shallow and deep ground water; however, the risks associated with the elevated levels of COC in this areas would be adequately addressed through the deed restriction.

3.2.6.2 Implementability

At low-flow rates, ground-water extraction would be readily implementable in shallow and deep ground-water source areas; however, it would be difficult to establish an effective extraction system in bedrock and in shoreline areas. The treatment processes for the extracted ground water would be readily implementable (although skilled operators would be required) because standard unit processes would be utilized. Conducting a long-term monitoring program will be readily implementable because the existing monitoring well network can be used or readily modified.

3.2.6.3 Cost

The costs associated with Alternative 6 include installation of ground-water extraction wells, long-term O&M of the extraction and treatment system, and long-term monitoring (Appendix B).

Capital Cost =	$ 1,069,000
Annual O&M Cost =	$ 601,000
Total 30-year Present Worth =	$ 7,598,000

3.2.6.4 Conclusions

Through the deed restriction prohibiting the future use of site ground water and ground-water source area treatment, Alternative 6 would be effective for addressing the site risks and RAO. However, this pump-and-treat technique is not anticipated to be effective in the long-term due to high O&M requirements and costs as compared to the typical diminishing effectiveness over time. Therefore, Alternative 6 will not be retained for the Detailed Analysis.

4. DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

The Detailed Analyses of Alternatives presented in this chapter contains relevant information needed to allow decision-makers to select a site remedy and demonstrate satisfaction of the CERCLA remedy selection requirements for the ROD. A summary and comparison of the remedial alternatives is presented in Chapter 5.

4.1 REMEDIAL ACTION ALTERNATIVES RETAINED FOR DETAILED ANALYSIS

The following remedial alternatives were retained resulting from the development and screening of alternatives presented in Chapter 3:

- Alternative 1 - No Action
- Alternative 2 - Deed Restriction and Long-Term Monitoring
- Alternative 3 - *In-Situ* Anaerobic Bioremediation
- Alternative 4 - Vacuum-Vaporizer Wells
- Alternative 5 - *In-Situ* Permeable Reaction Wall

Alternatives retained to this point must be capable of achieving the RAO identified in Section 2.5. The exception to this is the "No Action" alternative, which is retained in order to provide a baseline for comparison of the other alternatives, pursuant to the NCP requirement. As discussed in Chapter 3, Alternative 6 (Ground-Water Extraction with *Ex-Situ* Air Stripping) was not retained for further consideration.

4.2 DESCRIPTION OF EVALUATION CRITERIA

Pursuant to EPA guidance, remedial alternatives must be examined for adherence to nine criteria, as specified in the NCP. These criteria are as follows:

1. Overall protection of human health and the environment
2. Compliance with ARARs
3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, and volume through treatment
5. Short-term effectiveness
6. Implementability
7. Cost
8. State acceptance
9. Community acceptance

The last two evaluation criteria, "State Acceptance" and "Community Acceptance," are not addressed until completion of the review and comment period for the RI/FS and Proposed Plan. Adherence to these criteria will be addressed in the ROD.

In order to facilitate a detailed evaluation of remedial alternatives, the following criteria and rationale were applied:

1. Overall Protection of Human Health and the Environment
   - Reduction of risks
   - Preservation of natural resources

2. Compliance With ARARs

   - Compliance with chemical-specific, action-specific, and location-specific ARARs, as well as other TBC guidances

3. Long-Term Effectiveness and Permanence

   - Magnitude of residual risk
   - Adequacy and reliability of controls

4. Reduction of Toxicity, Mobility, and Volume through Treatment

   - Treatment processes used and materials treated
   - Amount of hazardous materials destroyed or treated
   - Degree of expected reductions in toxicity, mobility, and volume
   - Degree to which treatment is irreversible
   - Type and quantity of residuals remaining after treatment

5. Short-Term Effectiveness

   - Protection of community and workers during remedial actions
   - Environmental impacts
   - Time until remedial action objectives are achieved

6. Implementability

   - Ability to construct and operate the technology
   - Availability and reliability of prospective technologies
   - Ease of undertaking additional remedial actions, if necessary
   - Ability to monitor effectiveness of remedy
   - Ability to obtain approvals from other agencies and coordination with those agencies
   - Availability of equipment and specialists and offsite treatment, storage and disposal services

7. Cost

    - Capital costs
    - Operation and maintenance costs
    - 30-year present worth costs

8. State Acceptance (not specifically addressed in the RI/FS process)

9. Community Acceptance (not specifically addressed in the RI/FS process)

Costs developed in this FS are based on 1998 dollars. Present worth costs are calculated using a 5% discount rate over a 30-year period of performance.

4.3 EVALUATION OF ALTERNATIVE 1: NO ACTION

4.3.1 Description

Pursuant to Section 300.430(e)(3)(ii)(6) of the revised NCP, the No Action alternative is presented as a baseline for comparison with other remedial alternatives. Under this alternative, no remedial actions or institutional controls would be implemented or maintained at the site. As required by CERCLA, there would be a need for 5-year reviews of the No Action alternative.

4.3.2 Detailed Evaluation

4.3.2.1 Overall Protection of Human Health and the Environment

The No Action alternative would not address site risks. Therefore, the No Action alternative would not be protective of human health. No unacceptable onsite or offshore ecological risks were identified for, or linked to, Site 07.

4.3.2.2 Compliance with ARARs

The No Action alternative will not address COC which have been detected at levels above RIDEM's Class GB ground-water standards. No institutional controls would be implemented to protect human health from the identified unacceptable risks associated with these elevated COC.

Location-specific ARARs identified for Site 07 are associated with the protection of wetlands and other resources during any remedial actions. Executive Order 11990 requires federal actions to be protective of natural and beneficial values of wetlands, including preventing threats from pollution. Because the No Action alternative does not address potential threats to wetlands from ground-water COC, this ARAR is not satisfied by Alternative 1. Because Alternative 1 does not include any remedial actions, there are no action-specific ARARs.

4.3.2.3 Long-Term Effectiveness and Permanence

The No Action alternative contains no remedial components or institutional controls for the long-term management of site risks. RAO established for the site would not be met. Because the risk to the future use of the site would not be abated, the NCP would require 5-year reviews of the No Action decision. Due to the remaining site risks, the No Action alternative will not be effective in the long-term.

4.3.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

No treatment would be specified under the No Action alternative. No other controls would be implemented to address the risks associated with the toxicity, mobility, and volume of COC at the site.

4.3.2.5 Short-Term Effectiveness

No remedial actions would be specified under the No Action alternative; therefore, there would be no increased risks to human health or the environment during implementation of this alternative. The No Action alternative would not result in onsite or offshore adverse environmental impacts (no onsite or offshore ecological risks have been identified under current conditions). The No Action alternative would not be effective in the short-term for addressing the site risks to human health.

4.3.2.6 Implementability

No remedial components would be specified; therefore, in a technical sense, the No Action alternative would be readily implementable. This alternative would not interfere with potential future remedial actions at the site or nearby IR Program sites, if necessary. However, because unacceptable risks would remain onsite, the No Action alternative will not be implementable.

4.3.2.7 Cost

There would be no capital costs for Alternative 1. O&M costs for Alternative 1 are only associated with the 5-year reviews and are anticipated to be nominal.

4.4 EVALUATION OF ALTERNATIVE 2: DEED RESTRICTION AND LONG-TERM MONITORING

4.4.1 Description

As described in Section 3.1.2, the remedial components of Alternative 2 consist of a deed restriction prohibiting the future use of site ground water, long-term monitoring to ensure that the site continues to pose no unacceptable risk, and 5-year reviews.

Under Alternative 2, a deed restriction prohibiting the future use of site ground water will be implemented to address site risks. According to the HHRA for Site 07, unacceptable risks to human health at the site only were associated with the consumption and use (showering) of deep and bedrock ground water. A deed restriction which will control the use of ground water at the site will address these risks to human health. Periodic inspections of the land use will be conducted to ensure that the deed restriction remains effective.

As required by CERCLA Section 121(c), 5-year reviews will be conducted because COC will be left onsite above the established health-based levels. A long-term monitoring program including selected upgradient, downgradient, and side-gradient wells will be conducted as part of Alternative 2. The scope of the long-term monitoring program (e.g., specific well locations, sampling frequency, analytical parameters, exit criteria, action levels) is being developed in a Long-Term Risk Monitoring Plan for Site 07. The monitoring events will account for seasonal variations such as changed in the water table levels. Upgradient wells (potentially MW07-22S/D) would be used to characterize ground water entering Site 07 (i.e., background wells) and to ensure that the COC plume is not migrating north toward offsite Class GA aquifers. Downgradient wells would focus on potential discharge areas (e.g., where the plume appears to be rising from the deep to the shallow aquifer). Side-gradient wells would be used to confirm that the plume will not significantly increase in lateral extent. As warranted based upon trends observed from the ground-water data, the monitoring program could also include seep/sediment sampling from the shoreline and seep/sediment samples from the interior wetlands area. Samples collected during the monitoring program will be analyzed for the Site 07 COC. The overall long-term monitoring program will be flexible in scope to respond to trends observed in the ground-water COC data. If, during the review periods, future remedial action or additional monitoring should prove necessary, appropriate risk reduction measures can then be further evaluated.

4.4.2 Detailed Evaluation

4.4.2.1 Overall Protection of Human Health and the Environment

Alternative 2 would be protective of human health through a deed restriction prohibiting the future use of site ground water. According to the HHRA for Site 07, unacceptable risks to human health were associated with the consumption and use (showering) of deep and bedrock ground water. A deed restriction which controls the use of ground water at the site would address these risks to human health. Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely to become a source for potable water in the future (1) due to the high salinity identified beneath much of the site, (2) due to the availability of public water adjacent to the site, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations.

No unacceptable ecological risks have been linked to Site 07; therefore, no further remedial components would be required in order to manage risk at Site 07. According to the Freshwater/Terrestrial ERA, there are no unacceptable ecological risks on Site 07 and, according to the Marine ERA, the identified ecological risks in Allen Harbor have not been linked to Site 07. COC migration from Site 07 does not appear to be adversely impacting Allen Harbor because the site COC (chlorinated VOC) have not been identified in shoreline sediment or shellfish populations. After 23 to 37 years of plume migration, no unacceptable ecological risk has been identified offshore and no new risks are anticipated. Furthermore, migration beyond the shoreline would discharge to Narragansett Bay where dilution would mitigate COC concentrations.

The 5-year reviews and monitoring program will be protective of human health and the environment by ensuring that any changes in the plume or site use would not generate unacceptable risks.

4.4.2.2 Compliance with ARARs

No chemical-specific ARARs were identified for Site 07. The deed restriction under Alternative 2 will address the risks associated with elevated COC concentrations as identified during the HHRA. The action-specific performance standards will be used to evaluate this remedial alternative's protection of human health and the environment.

The monitoring program under Alternative 2 will be performed in accordance with the identified location- and action-specific ARARs (Tables 3-2 and 3-3, respectively).

4.4.2.3 Long-Term Effectiveness and Permanence

The deed restriction prohibiting the future use of site ground water specified under Alternative 2 will be effective in the long-term for addressing site risks. The 5-year reviews and monitoring program will be effective for evaluating the long-term adequacy, protection, and reliability of Alternative 2.

4.4.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

No treatment would be specified under Alternative 2; however, the risks associated with the toxicity, mobility, and volume of COC would be addressed through the deed restriction and the long-term monitoring program.

4.4.2.5 Short-Term Effectiveness

The deed restriction under Alternative 2 will be effective in the short-term for addressing site risks to human health. Site risks would be addressed immediately with implementation of the deed restriction. No unacceptable onsite or offshore ecological risks were identified at or linked to Site 07. Because no remedial activities are specified, no adverse impacts to the community or the environment would result from implementation of this alternative.

4.4.2.6 Implementability

Alternative 2 is technically implementable at Site 07. The implementation requirements consist of creating a deed restriction prohibiting the future use of site ground water and conducting periodic reviews. A deed restriction would be readily implementable. The monitoring program will be readily implementable because the existing monitoring well network can be used or modified.

Administratively, no treatment may be implementable at Site 07 because no unacceptable site risks would remain and active remediation may not be practicable, cost-effective, or warranted. Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely become a source for drinking water in the future (1) due to the high salinity, (2) due to the availability of public water adjacent to Calf Pasture Point, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations. Treatment may also not be warranted or practicable because (1) the identified unacceptable risks to human health can be addressed through a deed restriction, (2) no significant onsite ecological risks were identified, (3) no unacceptable risks from Site 07 were identified in offshore areas, and (4) locating and treating COC contained in bedrock fractures and potential residual DNAPL contained in soil void spaces at the source can be technically impracticable. The monitoring program will ensure that the site continues to pose no unacceptable risk to human health and the environment.

4.4.2.7 Cost

Capital costs and annual O&M costs for Alternative 2 are presented in Tables 4-1 and 4-2, respectively. Capital costs consist of an estimated $130,000. Annual O&M costs ($247,000) are associated with the long-term monitoring program. The total 30-year present worth cost of Alternative 2 is $1,679,000.

4.5 EVALUATION OF ALTERNATIVE 3: *IN-SITU* ANAEROBIC BIODEGRADATION

4.5.1 Description

As detailed in Section 3.1.3, the remedial actions under Alternative 3 consist of a deed restriction prohibiting the future use of site ground water to address site risks, *in-situ* anaerobic bioremediation to reduce COC concentrations in shallow and deep ground-water source areas, long-term monitoring, and 5-year reviews.

A deed restriction appropriate to development of the site and use of site ground water would be implemented to address site risks. According to the HHRA for Site 07, unacceptable risks to human health were associated with the consumption and use (showering) of deep and bedrock ground water. A deed restriction which controls the use of ground water at the site would address the identified risks to human health. Periodic inspections of the land use will be conducted to ensure that the deed restriction remains effective. No unacceptable onsite or offshore ecological risks were identified at or linked to Site 07.

In-situ anaerobic biodegradation would be performed through injection of an aqueous substrate into the primary affected regions of the aquifer. This substrate would provide nutrients and a carbon source for the intrinsic microbial population in the subsurface. Bacteria would consume this food source and, in the process, dissolved oxygen (which acts as a terminal electron acceptor in the bacteria's metabolism for converting food to energy). The bacteria will then begin to use the chlorinated organic compounds as an oxygen substitute, thereby degrading the dissolved organic COC.

As required by CERCLA Section 121(c), 5-year reviews will be conducted because COC would be left onsite above the established health-based levels. Under this alternative, a treatability study and a tracer study would be performed to evaluate and optimize the system. During operation of the injection system, ground-water monitoring will be performed to evaluate its effectiveness. The existing monitoring well network will be used or modified. A long-term monitoring program including selected upgradient, downgradient, and side-gradient wells will also be conducted as part of Alternative 3. The scope of the long-term monitoring program (e.g., specific well locations, sampling frequency, analytical parameters, exit criteria, action levels) is being developed in a Long-Term Risk Monitoring Plan for Site 07. The monitoring events will account for seasonal variations such as changes in the water table level. Upgradient wells (potentially MW07-22S/D) will be used to characterize ground water entering Site 07 (i.e., background wells) and to ensure that the COC plume is not migrating north toward offsite Class GA aquifers. Downgradient wells will focus on potential discharge areas (e.g., where the plume appears to be rising from the deep to the shallow aquifer). The side-gradient wells will be used to confirm that the plume will not significantly increase in lateral extent. As warranted based upon trends observed from the ground-water data, the monitoring program could also include seep/sediment sampling from the shoreline and seep/sediment samples from the interior wetlands area. Samples collected during the monitoring program will be analyzed for the Site 07 COC. The overall long-term monitoring program will be flexible in scope to respond to trends observed in the ground-water COC data. If, during the review periods, future remedial action or additional monitoring should prove necessary, appropriate risk reduction measures can then be further evaluated. As feasible to avoid redundancies, monitoring for treatment system performance will be conducted in conjunction with monitoring of the plume.

This alternative will not likely treat bedrock ground water, downgradient portions of the plume, or arsenic in ground water; however, the risks associated with the elevated levels of COC in these areas would be addressed through the deed restriction.

4.5.2 Detailed Evaluation

4.5.2.1 Overall Protection of Human Health and the Environment

Alternative 3 will be protective of human health and the environment. *In-situ* bioremediation would reduce organic COC concentrations in shallow and deep ground-water source areas. Downgradient portions of the plume, bedrock ground water, and arsenic in ground water would not be treated; however, the associated risks would be addressed through the deed restriction. According to the HHRA for Site 07, unacceptable risks to human health were associated with the consumption and use (showering) of deep and bedrock ground water. A deed restriction which controls the use of ground water at the site will address the identified risks to human health. No unacceptable ecological risks have been identified at, or linked to, Site 07. According to the Freshwater/Terrestrial ERA, there are no unacceptable ecological risks on Site 07 and, according to the Marine ERA, the identified ecological risks in Allen Harbor have not been linked to Site 07. Disposals at Site 07 occurred between 23 and 37 years ago; thus, no new risks are anticipated (e.g., it appears that remnants of past disposals such as non-empty canisters no longer remain at the site based upon the results of several geophysical investigations and ground-water data from the Phase I, II, and III RI reports). After 23 to 37 years of plume migration, no unacceptable ecological or human health risks from Site 07 have been identified offshore.

The 5-year reviews and long-term monitoring program will be protective of human health and the environment by ensuring that the site continues to pose no unacceptable risk to human health and the environment.

4.5.2.2 Compliance with ARARs

No chemical-specific ARARs were identified for Site 07. However, various COC in shallow, deep, and bedrock ground water were identified above RIDEM's Method 1 Class GB criteria. These action-specific performance standards would be used to evaluate the effectiveness of *in-situ* anaerobic biodegradation for addressing COC concentrations in shallow and deep ground-water source areas. The performance standards would also be used to evaluate this remedial alternative's protection of human health and the environment. Prior to full-scale implementation, the effectiveness of this alternative would be evaluated during a treatability study. The risks associated with areas not treated under Alternative 3 would be addressed through the deed restriction.

Alternative 3 will be performed in accordance with the identified location- and action-specific ARARs (Tables 3-4 and 3-5, respectively).

4.5.2.3 Long-Term Effectiveness and Permanence

In-situ anaerobic bioremediation may be effective in the long-term for reducing chlorinated VOC concentrations in shallow and deep ground-water source areas at Site 07. However, bioremediation may not be effective for treating arsenic or residual DNAPL potentially present in the vicinity of MW07-04D, MW07-05D, MW07-15D, and MW07-17D (due to toxicity to bacteria—however, this technology may be amenable for the treatment of dissolved-phase VOC). A treatability study will be conducted to confirm and optimize the effectiveness of this technology. Biodegradation of site COC represents a permanent solution because the chlorinated VOC would be converted to innocuous compounds rather than being transferred to another media requiring separate treatment and/or disposal. *In-situ* anaerobic bioremediation will not be effective for reducing COC concentrations in bedrock ground water due to the technical difficulties associated with mass transfer in fractured bedrock; however, the deed restriction and the monitoring program will be effective in the long-term for addressing and evaluating areas which would not be treated by this alternative.

4.5.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 3 will reduce the toxicity, mobility, and volume of organic COC in shallow and deep ground water through *in-situ* anaerobic biodegradation. The COC identified at Site 07, with the exception of arsenic, should be degradable with this process. The risk associated with the ingestion of arsenic in ground water would be addressed through the deed restriction. The efficiency for *in-situ* anaerobic biodegradation for achieving PRG would be determined as part of a pre-design treatability study. This technology will provide an irreversible treatment because biodegradation would result in the destruction of COC rather than transfer to another media requiring subsequent treatment and/or disposal.

Biodegradation will transform the chlorinated VOC into less toxic compounds. A possible exception of this would be an intermediate degradation compound of VC resulting from the biodegradation of DCE. Complete chemical and biological degradation of chlorinated VOC will result in non-toxic compounds such as ethenes/ethanes, carbon dioxide, chloride, and water. A possible exception for the reduction of mobility may be associated with the partial biodegradation by-products of some VOC which have higher mobility in ground water (e.g., trans-1,2-DCE has a higher mobility than TCE as evidenced by its lower K_{oc} value).

No active remedial treatments are specified for bedrock ground water and downgradient portions of the plume; however the risks associated with the toxicity, mobility, and volume of COC in these areas would be addressed through the deed restriction and the long-term monitoring program.

Injection rates will have to be maintained at a sufficiently low rate in order to prevent increasing the mobility of ground-water COC. A low injection rate (Section 3.1.3) would be used in order to prevent an upward gradient of the deep aquifer which potentially could increase the mobility of COC from the till toward the silt or the upper sand units.

4.5.2.5 Short-Term Effectiveness

Anaerobic biodegradation processes can be slow due to the slower metabolism of anaerobic bacteria (as compared to aerobic bioremediation processes). The time to remediate the site under this alternative would be estimated based upon the results of the treatability study. A deed restriction will be immediately effective for preventing potential human exposure to affected ground water while remedial actions are being conducted.

Standard safety controls and equipment (e.g., personal protective equipment, field screening equipment) would be used to protect site workers (e.g., construction, operation, and sampling crews) during remedial actions. Injection wells would only be used to inject a biodegradable solution of an organic substrate in water; therefore, no adverse environmental impacts would result from implementation of this alternative (provided that a low injection rate is used to prevent plume migration into the upper geological units).

4.5.2.6 Implementability

Alternative 3 may be implementable at Site 07 but with some operation and design difficulties. The technical and administrative implementation requirements would consist of creating a deed restriction, conducting a treatability study, installing and operating a series of wells to inject a carbon source for bacteria in the shallow and deep ground-water source areas, and establishing a long-term monitoring program.

A long-term monitoring program will be readily implementable because the existing monitoring well network can be used or modified. The required materials and services for sampling, sample analyses, and well maintenance are readily available.

A treatability study designed to examine the effectiveness of *in-situ* anaerobic biodegradation should be implementable; however, interpretation of the results can be difficult [e.g., differentiating between biodegradation and natural fluctuations in the monitoring program, determining the optimal organic source type and mass injection rate, promoting the growth of anaerobic bacteria (which have slower metabolisms than aerobic bacteria)]. Operation and design difficulties for the full-scale process include providing skilled operators, maintaining a strong anaerobic bacterial population over time, and optimizing the proper injection well positions (lateral distribution and depth of screening) and flow rates such that mass transfer limitations do not hinder the anaerobic biodegradation process. Mass transfer limitations typically are the primary limiting factor for operation of an *in-situ* bioremediation system. Administratively, some reluctance may be encountered because the effectiveness of this innovative technology has not been proven; however, a successful treatability study would address such concerns.

Administratively, no treatment of the downgradient portions of the plume and bedrock ground water may be implementable at Site 07 because the associated risks would be addressed through the deed restriction and active remediation may not be practicable, cost-effective, or warranted. Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely become a source for drinking water in the future (1) due to the high salinity, (2) due to the availability of public water adjacent to Calf Pasture Point, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations. Treatment may also not be warranted or practicable because (1) the identified unacceptable risks to human health can be addressed through a deed restriction, (2) no significant onsite ecological risks were identified, (3) no site-related COC have been identified in downgradient environmental media (shoreline sediment or shellfish), and (4) locating and treating COC contained in bedrock fractures and potential residual DNAPL contained in soil void spaces at the source can be technically impracticable.

4.5.2.7 Cost

Capital costs for Alternative 3 are presented in Table 4-3. Capital costs ($1,000,000) consist of implementing a deed restriction, conducting a treatability study, and installing injection wells. Annual O&M costs ($468,000) consist of system operation and long-term monitoring. Annual O&M costs for Alternative 3 are presented in Table 4-4. The total 30-year present worth cost of Alternative 3 is estimated to be $ 3,619,000.

4.6 EVALUATION OF ALTERNATIVE 4: VACUUM-VAPORIZER WELLS

4.6.1 Description

As detailed in Section 3.1.4, the remedial actions under Alternative 4 consist of a deed restriction to address site risks, conducting a pilot study, installation and operation of Vacuum-Vaporizer Wells to reduce ground-water COC concentrations in the shallow and deep ground-water source areas, long-term monitoring, and 5-year reviews.

Under Alternative 4, a deed restriction prohibiting the future use of site ground water would be implemented to address site risks. According to the HHRA for Site 07, unacceptable risks to human health were associated with the consumption and use (showering) of deep and bedrock ground water. A deed restriction which controls the use of ground water at the site will address the identified risks to human health. Periodic inspections of the land use will be conducted to ensure that the deed restriction remains effective. No unacceptable onsite or offshore ecological risks were identified at or linked to Site 07.

A pilot study would be performed to evaluate the effectiveness of Vacuum-Vaporizer Wells at Site 07 as well as to optimize the well design and system operation. The full-scale system would include three Vacuum-Vaporizer Wells installed around the deep ground-water source area (near the original DANC disposal area) and one Vacuum-Vaporizer Well installed within the shallow ground-water source area (at MW07-19S). Offgas from the Vacuum-Vaporizer Wells would be manifolded into a central, onsite GAC treatment unit prior to discharge to the atmosphere.

Vacuum-Vaporizer Wells system would not likely treat bedrock ground water or downgradient portions of the plume; however, the risks associated with the elevated levels of COC in these areas would be addressed through the deed restriction.

As required by CERCLA Section 121(c), 5-year reviews will be conducted because COC would be left onsite above the established health-based levels. A long-term monitoring program including selected upgradient, downgradient, and side-gradient wells will be conducted as part of Alternative 4. The scope of the long-term monitoring program (e.g., specific well locations, sampling frequency, analytical parameters, exit criteria, action levels) is being developed in a Long-Term Risk Monitoring Plan for Site 07. The monitoring events will account for seasonal variations such as changes in the water table level. Upgradient wells (potentially MW07-22S/D) will be used to characterize ground water entering Site 07 (i.e., background wells) and to ensure that the COC plume is not migrating north toward offsite Class GA aquifers. Downgradient wells will focus on potential discharge areas (e.g., where the plume appears to be rising from the deep to the shallow aquifer). Side-gradient wells will be used to confirm that the plume will not significantly increase in lateral extent. As warranted based upon trends observed from the ground-water data, the monitoring program could also include seep/sediment sampling from the shoreline and seep/sediment samples from the interior wetlands area. Samples collected during the monitoring program will be analyzed for the Site 07 COC. The overall long-term monitoring program will be flexible in scope to respond to trends observed in the ground-water COC data. If, during the review periods, future remedial action or additional monitoring should prove necessary, appropriate risk reduction measures can then be further evaluated. As feasible to avoid redundancies, monitoring for treatment system performance will be conducted in conjunction with monitoring of the plume.

4.6.2 Detailed Evaluation

4.6.2.1 Overall Protection of Human Health and the Environment

Alternative 4 will be protective of human health and the environment. Vacuum-Vaporizer Wells will reduce COC concentrations in shallow and deep ground-water source areas. Downgradient portions of the plume and bedrock ground water would not be treated; however, the risks associated with COC in these areas would be addressed through the deed restriction prohibiting the future use of site ground water. According to the HHRA for Site 07, unacceptable risks to human health were associated with the consumption and use (showering) of deep and bedrock ground water. A deed restriction which controls the use of ground water at the site will address the identified risks to human health. No unacceptable ecological risks have been identified at, or linked to, Site 07. According to the Freshwater/Terrestrial ERA, there are no unacceptable ecological risks on Site 07 and, according to the Marine ERA, the identified ecological risks in Allen Harbor have not been linked to Site 07. COC migration from Site 07 does not appear to be adversely impacting Allen Harbor because the site COC (chlorinated VOC) have not been identified in shoreline sediment or shellfish populations. Disposals at Site 07 occurred between 23 and 37 years ago; thus, no new risks are anticipated (e.g., it appears that remnants of past disposals such as non-empty canisters no longer remain at the site based upon the results of several geophysical investigations and ground-water data from the Phase I, II, and III RI reports). After 23 to 37 years of plume migration, no unacceptable ecological risk has been identified offshore.

The 5-year reviews and long-term monitoring program will be protective of human health and the environment by ensuring that the site continues to pose no unacceptable risk to human health and the environment.

4.6.2.2 Compliance with ARARs

No chemical-specific ARARs were identified for Site 07; however, various COC in shallow, deep, and bedrock ground water were identified above RIDEM's Method 1 Class GB criteria. These action-specific performance standards would be used to evaluate the effectiveness of the Vacuum-Vaporizer Well system to address COC concentrations in shallow and deep ground-water source areas. The performance standards would also be used to evaluate this remedial alternative's protection of human health and the environment. Prior to full-scale implementation, the effectiveness of the system would be evaluated through a treatability study. The risks associated with areas not treated under Alternative 4 would be addressed through the deed restriction.

Alternative 4 will be performed in accordance with the identified location- and action-specific ARARs (Tables 3-6 and 3-7, respectively).

4.6.2.3 Long-Term Effectiveness and Permanence

A Vacuum-Vaporizer Well system may be effective for reducing chlorinated VOC concentrations in shallow and deep ground-water source areas. A pilot study will be conducted to confirm and optimize the effectiveness of this innovative/emerging technology. Vacuum-Vaporizer Wells would remove VOC from shallow and deep ground water and transfer these compounds to an onsite GAC unit. Upon breakthrough, this canister would be replaced and the spent GAC would be regenerated and reused or properly disposed offsite.

Vacuum-Vaporizer Wells may not be effective for treating bedrock ground water due to the technical difficulties associated with locating and treating preferential flow paths through bedrock fractures. Also, Vacuum-Vaporizer Wells may not be effective in all areas of Site 07 due to an extensive silt layer which would inhibit ground-water circulation between the upper and lower screened portions of the Vacuum-Vaporizer Wells. However, a deed restriction and the monitoring program will be effective in the long-term for addressing and evaluating the risks associated with deep ground water as well as downgradient portions of the plume.

4.6.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 4 will reduce the mobility and volume of organic COC in shallow and deep ground-water source areas through operation of a Vacuum-Vaporizer Well system. Alternative

4 will reduce the toxicity of the ground water within the treated portions of the plume through the removal of VOC. Except for arsenic, the COC identified at Site 07 should be amenable to this process. The risk associated with the ingestion of arsenic in ground water would be addressed through the deed restriction. The efficiency for this system to achieve performance standards would be determined during a treatability study. In a full-scale system, the wells would be used to remove COC from the shallow and deep ground-water source areas and transfer these organic compounds to a *ex-situ* GAC unit. The spent GAC will require subsequent regeneration or offsite disposal. No active remedial treatments are specified for bedrock ground water and downgradient portions of the plume; however the risks associated with the toxicity, mobility, and volume of COC in these areas would be addressed through the deed restriction.

4.6.2.5 Short-Term Effectiveness

The time to remediate the site under this alternative would be estimated based upon the results of the treatability study. The deed restriction will be immediately effective for preventing potential human exposure to affected ground water while remedial actions are being conducted.

Standard safety controls and equipment (e.g., personal protective equipment, field screening equipment) would be used to protect site workers (e.g., construction, operation, and sampling crews) during remedial actions. Offgas from the system will be treated, as necessary, with GAC prior to discharge to the atmosphere; therefore, no adverse environmental impacts would result from system operation.

4.6.2.6 Implementability

Alternative 4 is anticipated to be implementable at Site 07 with some design difficulties. The technical and administrative implementation requirements would consist of creating a deed restriction prohibiting the future use of site ground water, conducting a pilot study, installing and operating a series of Vacuum-Vaporizer Wells within the shallow and deep ground-water source areas, and establishing a long-term monitoring program.

A long-term monitoring program will be readily implementable because the existing monitoring well network can be used or modified. The required services for sampling, sample analyses, and well maintenance are readily available.

A pilot study designed to examine the effectiveness of Vacuum-Vaporizer Wells should be implementable; however, interpretation of the results can be difficult. Operation and design difficulties for the full-scale process include determining proper injection well locations (lateral distribution and depth of screening) and flow rates. Vacuum-Vaporizer Wells could not be located in areas with a pronounced silt unit (i.e., a sufficient till and/or sand layer must be present). The wells will have to be installed in areas where the silt layer is reduced (e.g., just outside the suspected source area near MW07-05D) or not present (i.e., between MW07-26S and MW07-21S). Administratively, some reluctance may be encountered because this is an innovative technology; however, a successful pilot study would address such concerns.

Administratively, no treatment of the downgradient portions of the plume and bedrock ground water may be implementable at Site 07 because the associated risks would be addressed through the deed restriction and monitoring program and because active remediation may not be practicable, cost-effective, or warranted. Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely become a source for drinking water in the future (1) due to the high salinity, (2) due to the availability of public water adjacent to Calf Pasture Point, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations. Treatment may also not be warranted or practicable because (1) the identified unacceptable risks to human health can be addressed through a deed restriction, (2) no significant onsite ecological risks were identified, (3) no site-related COC have been identified in downgradient environmental media (shoreline sediment or shellfish), and (4) locating and treating COC contained in bedrock fractures and potential residual DNAPL contained in soil void spaces at the source can be technically impracticable.

4.6.2.7 Cost

Capital costs for Alternative 4 are presented in Table 4-5. Capital costs ($1,383,000) consist of implementing a deed restriction, conducting a pilot study, and installing a Vacuum-Vaporizer Well system. Annual O&M costs ($468,000) consist of system operation and long-term monitoring. Annual O&M costs for Alternative 4 are presented in Table 4-6. The total 30-year present worth cost of Alternative 4 is estimated to be $5,867,000.

4.7 EVALUATION OF ALTERNATIVE 5: *IN-SITU* PERMEABLE REACTION WALL

4.7.1 Description

As detailed in Section 3.1.5, the remedial actions under Alternative 5 consist of a deed restriction prohibiting the future use of site ground water to address site risks, installation of sheet pile walls to channel the shallow/deep ground-water plume through an *in-situ* permeable, reactive wall that will promote the degradation of most chlorinated organic COC, long-term monitoring, and 5-year reviews.

Under Alternative 5, a deed restriction prohibiting the future use of site ground water would be implemented to address site risks. According to the HHRA for Site 07, unacceptable risks to human health were associated with the consumption and use (showering) of deep and bedrock ground water. A deed restriction would address the identified risks to human health. Periodic inspections of the land use will be conducted to ensure that the deed restriction remains effective. No unacceptable onsite or offshore ecological risks were identified at or linked to Site 07.

A bench-scale treatability study (Section 3.1.5) would be performed to determine the effectiveness of this innovative/emerging technology for Site 07 COC and to optimize the design parameters for the full-scale system. Following the treatability study, the full-scale system could be constructed by installing sheet pile walls along the eastern and western sides of the ground-water plume. These walls would be installed down to the bedrock surface in order to channel both shallow and deep ground water through the permeable reaction wall which will be installed along the southern shoreline. This treatment zone would be constructed with a sheet pile wall containing intermittent permeable treatment sections along its length. Treated ground water exits the downgradient side of the reaction wall. Performance of this system would be evaluated using several piezometers and selected monitoring wells.

Piezometers would be placed on either side of the sheet pile walls at selected locations to evaluate the effectiveness for controlling shallow and deep ground-water flow (e.g., monitoring ground-water levels and/or COC concentrations across the sheet pile walls). Selected monitoring wells located downgradient of the sheet pile walls would also be sampled for selected COC. Additional shallow and deep monitoring wells will be installed on the downgradient (shoreline) side of the reaction wall in order to evaluate the effectiveness for reducing COC concentrations. This alternative will not treat some constituents (arsenic, benzene, and 1,2-DCA), bedrock ground water, or shallow/deep ground-water source areas; however, the associated risks would be addressed through the deed restriction.

As required by CERCLA Section 121(c), 5-year reviews will be conducted because COC would be left onsite above the established health-based levels. A long-term monitoring program will also be conducted as part of Alternative 5. This long-term monitoring program will be similar to those specified under Alternatives 2 through 4; however, there would be some modifications in order to avoid redundancies with the performance evaluation monitoring program. Shallow and deep side-gradient wells may not be required because the steel sheet piling would control ground-water flow above bedrock. Side-gradient piezometers will be used to evaluate the effectiveness for the sheet pile walls to control shallow and deep ground-water flow. Side-gradient bedrock monitoring wells will still be required because the sheet pile walls will not extend into bedrock to control ground-water flow in that region. The scope of the long-term monitoring program (e.g., specific well locations, sampling frequency, analytical parameters, exit criteria, action levels) is being developed in a Long-Term Risk Monitoring Plan for Site 07. The monitoring events will account for seasonal variations such as changes in the water table level. Upgradient wells (potentially MW07-22S/D) will be used to characterize ground water entering Site 07 (i.e., background wells) and to ensure that the COC plume is not migrating north toward offsite Class GA aquifers. As warranted based upon trends observed from the ground-water data, the monitoring program could also include seep/sediment sampling from the shoreline and seep/sediment samples from the interior wetlands area. Samples collected during the monitoring program will be analyzed for the Site 07 COC. The overall long-term monitoring program will be flexible in scope to respond to trends observed in the ground-water COC data. If, during the review periods, future remedial action or additional monitoring should prove necessary, appropriate risk reduction measures can then be further evaluated.

4.7.2 Detailed Evaluation

4.7.2.1 Overall Protection of Human Health and the Environment

Alternative 5 will be protective of human health and the environment. This system will reduce COC concentrations in shallow and deep ground water exiting Site 07. Alternative 5 would not treat shallow/deep ground-water source areas or bedrock ground water; however the risks associated with elevated levels of COC in these areas would be addressed through the deed restriction. According to the HHRA for Site 07, unacceptable risks to human health were associated with the consumption and use (showering) of deep and bedrock ground water. A deed restriction which controls the use of ground water at the site will address the identified risks to human health. No unacceptable ecological risks have been identified at, or linked to, Site 07. According to the Freshwater/Terrestrial ERA, there are no unacceptable ecological risks on Site 07 and, according to the Marine ERA, the identified ecological risks in Allen Harbor have not been linked to Site 07. COC migration from Site 07 does not appear to be adversely impacting Allen Harbor because the site COC (chlorinated VOC) have not been identified in shoreline sediment or shellfish populations. Disposals at Site 07 occurred between 23 and 37 years ago; thus, no new risks are anticipated (e.g., it appears that remnants of past disposals such as non-empty canisters no longer remain at the site based upon the results of several geophysical investigations and ground-water data from the Phase I, II, and III RI reports). After 23 to 37 years of plume migration, no unacceptable ecological risk has been identified offshore.

The 5-year reviews and long-term monitoring program will be protective of human health and the environment by ensuring that the site continues to pose no unacceptable risk to human health and the environment.

4.7.2.2 Compliance with ARARs

No chemical-specific ARARs were identified for Site 07; however various COC in shallow, deep, and bedrock ground water were identified above RIDEM's Method 1 Class GB criteria. These action-specific performance standards would be used to evaluate the effectiveness of an *in-situ* permeable reaction wall system to address shallow and deep ground water exiting Site 07. The performance standards would also be used to evaluate this remedial alternative's protection of human health and the environment. Prior to full-scale implementation, the effectiveness of the system would be evaluated through a treatability study. This system will not treat ground-water source areas or bedrock ground water; however, the risks associated with areas not treated under Alternative 4 would be addressed through the deed restriction.

Alternative 5 will be performed in accordance with the identified location- and action-specific ARARs (Tables 3-8 and 3-9, respectively).

4.7.2.3 Long-Term Effectiveness and Permanence

An *in-situ* permeable reaction wall system may be effective for reducing chlorinated VOC concentrations migrating from Site 07 via shallow and deep ground water. This technology will not be effective for degrading benzene or 1,2-DCA; however, these compounds were infrequently detected (Table 2-4) and are not the primary risk-drivers at the site. This system also will not treat arsenic. A treatability study will be conducted to confirm and optimize the effectiveness of this innovative/emerging technology. With periodic maintenance of the permeable reaction wall (e.g., mixing and/or replacement of the iron-based catalyst within the treatment zones), Alternative 5 would be effective in the long-term for degrading most COC exiting Site 07.

The permeable reaction wall will not treat shallow/deep ground-water source areas or bedrock ground water; however, the deed restriction and the long-term monitoring program will be effective in the long-term for addressing and evaluating the associated risks in these areas.

4.7.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

A permeable reaction wall system will reduce the mobility of organic and inorganic COC at Site 07 by channeling shallow and deep ground water through a permeable reaction wall along the southern shoreline of the site. Potential plume expansion to the east or west would be prevented; however, because the original disposals occurred between 23 and 37 years ago, the extent of plume migration in these directions may be minimal (i.e., the preferential plume migration is toward the southern shoreline). The reaction wall will reduce the toxicity and volume of organic COC migrating from the site via shallow and deep ground water. The reaction wall will degrade organic COC to non-toxic compounds (e.g., hydrogen gas, ethanes, ethanes, methane, and chloride) rather than transferring these compounds to another media which would require subsequent treatment and/or disposal. An *In-Situ* Permeable Reaction Wall system may be able to reduce most COC concentrations to meet PRG in shallow and deep ground water exiting the site. However, this technology will not be effective for treating benzene or 1,2-DCA which were both identified above Method 1 criteria and AWQC; however, these compounds were infrequently detected and were not the primary human health risk-drivers at Site 07. This technology will also not be effective for treating arsenic in shallow or deep ground water. The risk associated with the ingestion of arsenic in ground water would be addressed through the deed restriction.

Alternative 5 will not reduce the toxicity or volume of COC within shallow/deep source areas and will not reduce the toxicity, mobility, or volume of COC in bedrock ground water (neither onsite nor exiting the site). However, the risks associated with the toxicity, mobility, and volume of COC in these areas would be addressed through the deed restriction.

4.7.2.5 Short-Term Effectiveness

A time-to-remediate the site under Alternative 5 would not be determined because the *In-Situ* Permeable Reaction Wall system would only address COC exiting Site 07 and not treat ground-water source areas. However, a deed restriction will be immediately effective for addressing site risks.

Standard safety controls and equipment (e.g., personal protective equipment, field screening equipment) would be used to protect site workers (e.g., construction, operation, and sampling crews) during remedial actions. Installation of sheet pile walls will generate high levels of noise (e.g., greater than 85 dB) throughout the Allen Harbor area; however, this would be only a short-term nuisance to the local community and would not likely generate noise levels of concern because of the distance of Site 07 to populated areas than for residential neighborhoods. Noise would more of a nuisance factor for users of Allen Harbor and Spink Neck. Other than a temporary disturbance of the shoreline habitat, no adverse environmental impacts would result from implementation of this alternative.

4.7.2.6 Implementability

Alternative 5 is anticipated to be implementable at Site 07. The technical and administrative implementation requirements would consist of creating a deed restriction, conducting a pilot study, installing the sheet pile walls and permeable reaction wall, and establishing a long-term monitoring program.

A long-term monitoring program will be readily implementable because the existing monitoring well network can be used or modified. The required services for sampling, sample analyses, and well maintenance are readily available.

Sheet pile walls would be keyed into bedrock to minimize short-circuiting of the system. Sheet pile walls would be installed below ground surface in deference to local concerns for the aesthetics of Allen Harbor. A bench-scale treatability study should be implementable; however, translating laboratory results to a full-scale system can be difficult. Design and installation difficulties for the full-scale process include determining the proper catalyst mixture, driving extensive lengths of sheet pile down to an uneven bedrock topography, installing a trench along a shoreline, and performing periodic maintenance/replacement of the permeable, reactive zones.

Administratively, no treatment of the shallow and deep ground-water source areas and bedrock ground water may be implementable at Site 07 because the associated risks would be addressed through the deed restriction and because active remediation may not be practicable, cost-effective, or warranted. Although Calf Pasture Point may become a recreational-use area, ground water at Site 07 would not likely become a source for drinking water in the future (1) due to the high salinity, (2) due to the availability of public water adjacent to Calf Pasture Point, and (3) because the impacted portion of the Calf Pasture Point aquifer was found to be low-yielding during the Navy's ground-water investigations. Treatment may also not be warranted or practicable because (1) the identified unacceptable risks to human health can be addressed through a deed restriction, (2) no significant onsite ecological risks were identified, (3) no site-related COC have been identified in downgradient environmental media (shoreline sediment or shellfish), and (4) locating and treating COC contained in bedrock fractures and potential residual DNAPL contained in soil void spaces at the source can be technically impracticable.

4.7.2.7 Cost

Capital costs for Alternative 5 are presented in Table 4-7. Capital costs ($6,285,000) consist of implementing a deed restriction, conducting a treatability study, installing sheet pile walls to channel ground water, installing a permeable reaction wall (including replacement or replenishment of the reaction wall, as required), and installation of monitoring wells to allow for sampling of ground water exiting the permeable reaction wall. Annual O&M costs ($357,000) consist of periodic reaction wall maintenance/replacement and long-term monitoring. Annual O&M costs for Alternative 5 are presented in Table 4-8. The total 30-year present worth cost of Alternative 5 is estimated to be $9,062,000.

5. COMPARISON OF REMEDIAL ALTERNATIVES

This chapter presents the second and final step of the Detailed Analysis of Alternatives in the FS process. Here, the remedial alternatives, which were evaluated individually against the NCP evaluation criteria in Chapter 4, are compared for their relative effectiveness for each of those criteria. The comparison of remedial alternatives is intended to identify the advantages and disadvantages of each alternative relative to one another based upon the nine criteria so that the key decision-making trade-offs can be identified. Relative comparisons will be drawn for the following alternatives which have been retained to this point in the FS process:

- Alternative 1 - No Action
- Alternative 2 - Deed Restriction and Long-Term Monitoring
- Alternative 3 - *In-Situ* Anaerobic Bioremediation
- Alternative 4 - Vacuum-Vaporizer Wells
- Alternative 5 - *In-Situ* Permeable Reaction Wall

A general comparison of the feasible remedial alternatives retained to this point is presented in Table 5-1. A summary of the comparative analysis is presented in Table 5-2. State acceptance and community acceptance will be addressed in the ROD.

5.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The unacceptable risks to human health at Site 07 are associated with the consumption and use (showering) of deep and bedrock ground water. Alternatives 2 through 5 will be equally protective of human health through implementation of a deed restriction prohibiting the future use of site ground water in order to address site risks. Calf Pasture Point will be transferred to the Town of North Kingstown as a public benefit conveyance for use as an open space/conservation area. Acquisition in this manner restricts the transferee to use the property for the purpose of a park and recreation in perpetuity with no opportunity for resale or commercial development. The responsibility to abide by any deed restriction on the use of site property will be that of the Town of North Kingstown in perpetuity. The Navy will conduct periodic inspections of the land use to ensure that the deed restriction remains effective. Alternative 1 (No Action) would not reduce risk to human health because potential exposure to deep and/or bedrock ground water would not be prevented.

No unacceptable onsite or offshore ecological risks were identified at, or associated with, Site 07; furthermore, the chemical constituents identified in offshore media (shoreline sediment or shellfish) were not attributed to Site 07 soil or ground water. Therefore, the remedial alternatives were not required to contain additional provisions specifically to address ecological risks.

Alternatives 3 through 5 provide for ground-water treatment; however, the risk management of Site 07, with respect to preventing exposure through ingestion or use of impacted ground water, can be addressed through a deed restriction alone. Alternatives 3 and 4 provide treatment of shallow and deep ground-water source areas. Treatment under Alternative 3 will address the largest extent of the shallow/deep ground-water source area. Alternative 4 treats a smaller portion of the source area because the effectiveness of Vacuum-Vaporizer Wells would be limited in many areas due to a substantial silt layer. Alternative 5 will not treat ground-water source areas, rather, impacted shallow and deep ground water would be treated exiting Site 07.

The 5-year reviews and long-term monitoring programs under Alternatives 2 through 5 will be equally protective of human health and the environment by ensuring that any changes in the plume or site use would not generate unacceptable risks. No long-term monitoring is specified under Alternative 1.

5.2 COMPLIANCE WITH ARARS

Alternative 1 (No Action) will not comply with ARARs because it would not address the unacceptable site risks. Alternatives 2 through 5 equally address the risks associated with the site COC through implementation of a deed restriction prohibiting the future use of site ground water, a long-term monitoring program, and 5-year reviews.

Although no chemical-specific ARARs were identified for Site 07, various chlorinated-VOC in ground water have been detected above RIDEM's Method 1 Class GB criteria, which are action-specific performance standards for Site 07. In order to address these performance standards, Alternatives 3 and 4 provide for the treatment of shallow and deep ground-water source areas. Because they employ innovative treatment technologies, the effectiveness of Alternatives 3 through 5 would have to be evaluated by conducting treatability studies. Alternative 3 may be more effective than Alternative 4 because a greater portion of the plume would be under the influence of the remediation system; Alternative 4 provides for source area treatment only. Alternative 5 would not reduce COC in ground-water source areas, rather, this alternative provides for the downgradient treatment of shallow and deep ground water exiting Site 07. Alternative 2 does not include treatment for ground-water COC which exceed RIDEM's Method 1 Class GB ground-water objectives; however, the risks associated with these elevated COC as identified during the HHRA (note: the HHRA performed during the Phase III RI is indicative of a site-specific Method 3 assessment allowable by RIDEM for the determination of remedial goals) would be addressed through a deed restriction prohibiting the future use of site ground water. Alternative 1 would not address elevated concentrations of COC in ground water.

Site 07 location-specific ARARs include the protection of marshes, wetlands, and endangered species. Alternative 1 would not be protective of isolated marshes/wetlands and, therefore, is not in compliance with applicable wetland protection standards. Alternative 2 would have minimal impact on the isolated marshes/wetlands or potential endangered species/species habitat because remedial activities under this alternative will only include long-term monitoring, mainly with the existing monitoring well network (additional monitoring wells may be required). Monitoring will be protective of wetland resources by ensuring that impacted ground water does not degrade wetland resources. Alternatives 3 and 4 may have some impact on the isolated marshes/wetlands or potential endangered species/species habitat resulting from the construction activities (e.g., drill rigs) associated with well installation and building an onsite pump system (Alternative 3) or offgas treatment system (Alternative 4). Alternative 5 would have the greatest potential for disturbing the isolated marshes/wetlands or potential endangered species/species habitat at Site 07 resulting from the installation of a sheet pile wall and permeable reaction wall surrounding the eastern, western, and southern sides of the plume. The majority of the marshes at Site 07 are located along the shoreline and the eastern extent of the site (where the walls would be installed). Potential disturbances from Alternative 5 include surficial effects resulting from trenching and sheet pile driving as well as potentially changing the extent of salt water intrusion into Site 07 (vegetation associated with salt water or brackish marsh areas may be adversely affected).

Alternatives 2 through 5 would be conducted in accordance with action-specific ARARs. The action-specific performance standards will be used to evaluate the effectiveness of Alternatives 2 through 5 for addressing elevated COC concentrations as well as their protection of human health and the environment. Action-specific ARARs were not identified for Alternative 1 because no remediation technologies are specified.

5.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

The No Action alternative would not be effective in the long-term because the identified unacceptable risks to human health would not be addressed. Alternatives 2 through 5 will be equally effective and permanent in the long-term for managing risk at Site 07 with the implementation of a deed restriction prohibiting the future use of site ground water, a long-term monitoring program, and 5-year reviews.

Alternatives 3 through 5 will be more effective than Alternatives 1 and 2 for reducing COC concentrations in shallow and deep ground water because these alternatives include ground-water treatment components. Ground-water treatment under Alternatives 3 would result in the degradation of dissolved-phase COC in shallow and deep ground-water source areas. The ground-water treatment component of Alternative 4 would transfer COC from shallow and deep ground-water source areas to another media (i.e., GAC) requiring subsequent treatment and/or disposal. Alternative 5 will degrade COC in shallow and deep ground water exiting Site 07. The deed restriction under Alternatives 2 through 5 would be equally effective in the long-term for addressing the risks associated with the untreated portions of the plume (including bedrock ground water). The Navy will conduct periodic inspections of the land use to ensure that the deed restriction remains effective in the long-term.

5.4 REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT

Alternatives 1 does not specify ground-water treatment which will reduce the toxicity, mobility, or volume of ground-water COC.

Alternative 2 does not specify ground-water treatment which will reduce the toxicity, mobility, or volume of ground-water COC; however, the risks associated with the toxicity, mobility, or volume of ground-water COC would be effectively addressed through the deed restriction and long-term monitoring program.

The treatment system under Alternative 3 may reduce the toxicity, mobility, and volume of dissolved-phase, organic COC in shallow and deep ground-water source areas through *in-situ* biodegradation. A possible exception to this would result from the incomplete biodegradation of DCE (thereby creating VC which is a more toxic compound than DCE). The resulting end-products of complete anaerobic biodegradation would be innocuous. Another possible exception for the reduction of mobility may be associated with the partial biodegradation by-products of some VOC which have higher mobility in ground water (e.g., trans-1,2-DCE has a higher mobility than TCE as evidenced by its lower K_{oc} value). This alternative will not likely treat arsenic in ground water, downgradient portions of the plume, bedrock ground water, or residual DNAPL potentially within the deep ground-water source area; however, the risks associated with the toxicity, mobility, or volume of COC in these areas would be effectively addressed through the deed restriction.

The treatment system under Alternative 4 would reduce the mobility and volume of volatile COC in shallow and deep ground-water source areas by removing and transferring VOC to an *ex-situ* GAC treatment unit. Alternative 4 would reduce the toxicity of the ground water within the treated portion of the plume. This alternative will not likely treat arsenic in ground water, downgradient portions of the plume, or bedrock ground water; however, the risks associated with the toxicity, mobility, or volume of COC in these areas would be effectively addressed through the deed restriction.

The treatment system under Alternative 5 will reduce the toxicity and volume of organic COC in shallow and deep ground water exiting Site 07 through the *in-situ* reactive wall. Alternative 5 would also reduce the mobility of the shallow and deep ground-water plumes at Site 07 through installation of steel sheetpile walls which would channel affected ground water through the *in-situ* treatment zone. This alternative will not treat some constituents (arsenic, benzene, and 1,2-DCA) in ground water exiting the site, ground-water source areas, or bedrock ground water; however, the risks associated with the toxicity, mobility, or volume of COC in these areas would be effectively addressed through the deed restriction.

Alternatives 3, 4, and 5 will provide more reduction of the toxicity, mobility, and/or volume of COC in shallow and deep ground water than Alternatives 1 and 2 because these options would specify treatment technologies. Because they specify innovative treatment technologies, the relative efficiencies of Alternatives 3, 4, and 5 for achieving PRG would have to be evaluated during treatability studies. Alternative 3 may provide the most reduction of COC in shallow and deep ground-water source areas because it treats the largest plume area. Alternative 4 will treat COC in a smaller region of the shallow and deep ground-water source areas. Alternative 5 will not treat ground-water source areas or bedrock ground water but will be the most effective for reducing the toxicity, mobility, and volume for COC in shallow and deep ground water exiting the site.

5.5 SHORT-TERM EFFECTIVENESS

The deed restriction prohibiting the future use of site ground water specified under Alternatives 2 through 5 will be equally effective in the short-term for addressing the risks at Site 07. The No Action alternative will not be effective for controlling risks at the site because no remedial actions or institutional controls would be implemented to prevent potential human exposure to deep/bedrock ground water.

Although not effective for addressing the identified risks in the short-term, Alternative 1 would not produce any new risks to the community or to site workers because no remedial actions would be specified. Alternative 2 would produce nominal risks to site workers during the long-term monitoring program (such risks can be mitigated through the use of proper personal protective equipment). During the construction activities for Alternatives 3, 4, and 5, potential hazards to site workers (e.g., construction, operation, and sampling crews) include potential dermal contact with, or inhalation of, VOC from affected site media. Of these, Alternative 3 would present the least risk to site workers because potential contact with COC would only occur during well installation and ground-water sampling. Alternative 4 would present some risk to site workers because, in addition to risks associated with well installation and ground-water sampling, COC could potentially be discharged to the atmosphere during operation of the Vacuum-Vaporizer Well system (however, GAC treatment will be used if these discharge levels are found to be unacceptable). Alternative 5 would present the most risk to site workers because, in addition to ground-water sampling, potential direct contact with affected media would result from trenching operations during construction of the *in-situ* reaction wall. Inhalation hazards associated with fugitive dust and/or volatilization of VOC from soil/ground water may also be a concern during excavation of the trench. With the implementation of adequate engineering controls (e.g., dust control) and safety controls/equipment (e.g., personal protective equipment, and field screening equipment), the remedial activities associated with Alternatives 3, 4, and 5 are not anticipated to present adverse impacts to site workers or the surrounding community.

Installation of sheet pile walls under Alternative 5 will generate high levels of noise (e.g., greater than 85 dB) throughout the Allen Harbor area; however, this would be only a short-term nuisance to the local community and would not likely generate noise levels of concern because of the distance of Site 07 to populated areas. Noise would more of a nuisance factor for users of Allen Harbor and Spink Neck than for residential neighborhoods. Other than a temporary disturbance of the shoreline habitat, no adverse environmental impacts would result from implementation of this alternative.

In the short-term, implementing Alternatives 1 and 2 will have the least adverse impacts to the environment because no construction activities would be specified (as previously described in Section 5.2). Implementing alternatives 3 and 4 would have minor adverse impacts to the environment, mainly associated with the temporary operation of construction equipment (e.g., drill rigs used for well installation). Implementing Alternative 5 would have the greatest adverse impacts to the environment due to heavy use of construction equipment during trenching and sheetpile wall installation as well as the periodic maintenance/replacement activities for the *in-situ* reactive wall sections.

5.6 IMPLEMENTABILITY

Although easy to implement in a technical sense (because no remedial actions would be specified), the No Action alternative will not be implemented because the unacceptable risks at Site 07 would not be addressed.

Alternative 2 would be readily implementable in a technical sense (because this would only require the preparation of a deed restriction and conducting a long-term monitoring program mainly with the existing monitoring well network). Furthermore, this alternative is also implementable in an administrative sense because all unacceptable risks would be addressed and ground-water treatment may not be warranted (e.g., ground water is not and is not likely to be a source for potable water, no evidence of offshore risks due to ground water have been identified, treatment of COC in bedrock ground water and potential residual DNAPL may be technically impracticable). The deed restriction specified under Alternatives 3, 4, and 5 would also be readily implementable.

The technical implementability of Alternatives 3, 4, and 5 will depend upon the results of the respective treatability/pilot studies. These alternatives should be implementable because the required technologies are based upon standard construction techniques. However, each of these are innovative technologies and the full-scale applications may have design and/or operational difficulties. Alternative 3 will require skilled operators, an ability to maintain a strong anaerobic bacterial population over time, and an optimization of injection well positions (lateral distribution and depth of screening) and flow rates such that mass transfer limitations do not hinder the anaerobic biodegradation process (mass transfer limitations typically are the primary limiting factor for the successful operation of an *in-situ* bioremediation system). Preferential channeling of the injected aqueous solution under Alternative 3 may result in untreated portions of the subsurface aquifer. Alternative 4 will also require skilled operators and optimizing well locations (lateral distribution and depth of screening) and flow rates. Preferential flow paths or channels throughout the radius of influence of the Vacuum-Vaporizer Wells under Alternative 4 also may result in untreated intervals of the subsurface aquifer. Alternative 5 will require careful design of the reactive wall (thickness, permeability, iron content) and substantial periodic maintenance (e.g., mixing and/or replacement of the reaction wall in order to replenish the iron content and/or to reduce the adverse effects of potential bicarbonate precipitates within the wall). The trenching required under Alternative 5 for the construction of the *In-Situ* Permeable Reaction Wall is a standard construction technique; however, this operation could be complicated by the proximity of Allen Harbor (which results in a shallow water table).

Because Alternatives 3, 4, and 5 are all innovative/emerging technologies, the reliability of these remedial actions is uncertain and vendors may be limited. The results of the treatability study for the selected alternative would better indicate the potential long-term reliability of these options.

Any additional remedial actions in the future, if required, would be easiest to implement under Alternatives 1 and 2. Potential future remedial actions would be relatively easy to implement under Alternatives 3 and 4 provided the above-ground components (e.g., manifold piping, GAC units, storage tanks) were not disturbed. Potential future remedial actions would be easy to implement under Alternative 5 provided they were not along the downgradient perimeter of the plume (where the sheet pile and reactive walls would be located).

For bedrock ground water, the treatment technologies specified under Alternatives 3 and 4 may not be implementable and, for Alternative 5, will not be implementable.

The long-term monitoring programs under Alternatives 2, 3, and 4 will be readily implementable because the existing monitoring well network can be used with some modifications/additions. The required equipment and services for sampling, analysis, and well maintenance are readily available. The long-term monitoring program under Alternative 5 will require a similar level of effort; however, additional monitoring wells would have to be installed along the southern shoreline of Site 07 as well as side-gradient piezometers. The required services for monitoring well and piezometer installations are readily available.

Due to the disturbance of the shoreline during vertical barrier installation under Alternative 5, construction activities will require coordination with RIDEM, the Rhode Island Coastal Resources Management Council (CRMC), as well as potentially the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Department of the Interior Fish and Wildlife Service. Alternatives 1 through 4 would have minimal impacts to the shoreline (e.g., only monitoring well installations, sampling events).

5.7 COST

The following statement of cost estimates is based upon a preliminary review of the anticipated requirements for each alternative, as presented in Chapter 4. The costs cited in this section are based upon approximate design specifications and vendor quotes, where possible. These preliminary cost estimates are anticipated to be within -30% to +50% of the actual costs for completing the remedial actions. Thus, these costs are primarily used as an order of magnitude comparison.

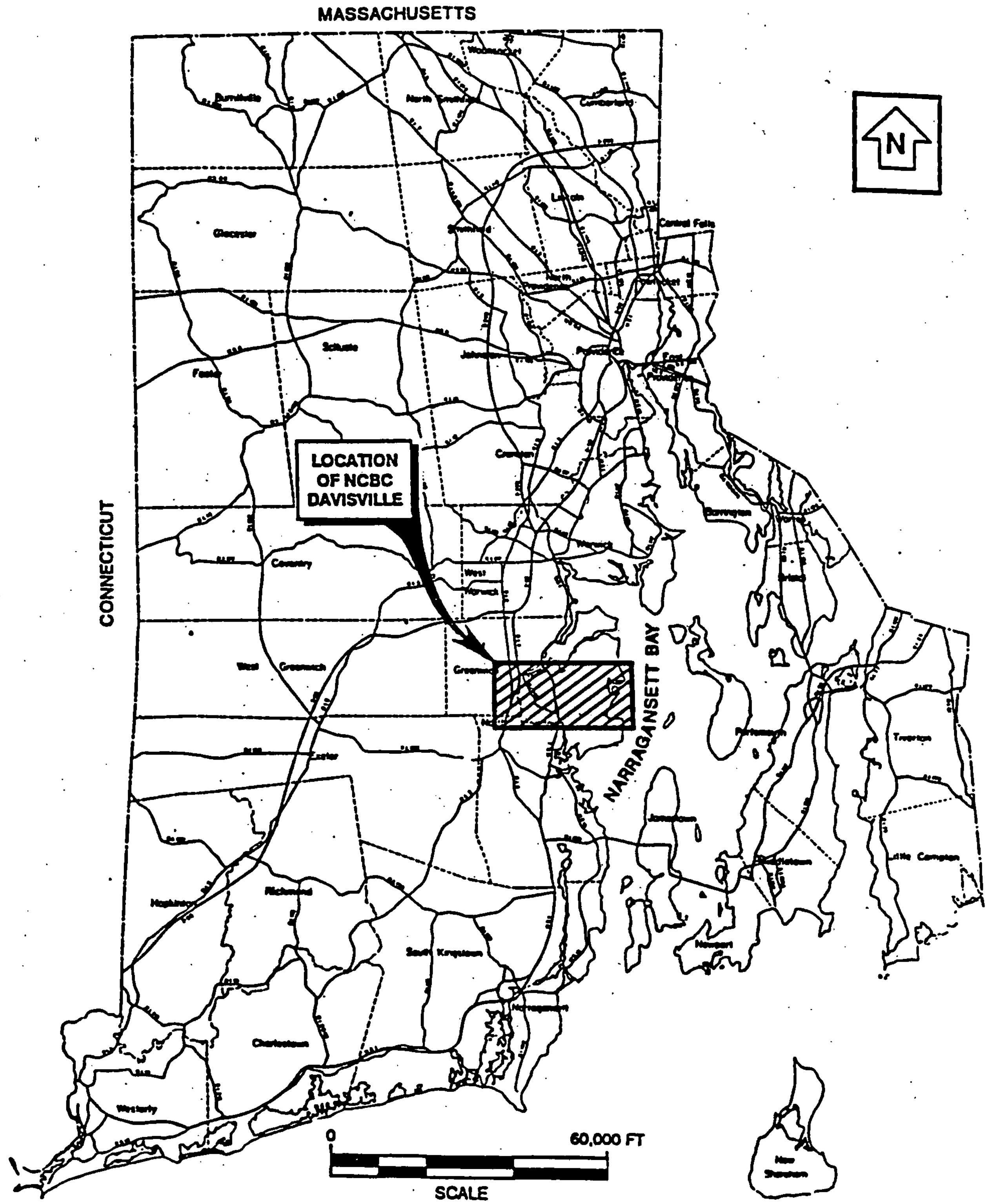
Costs for Alternative 1 (No Action) involve no capital costs. Costs for the 5-year reviews of the No Action decision are anticipated to be nominal.

Costs for Alternative 2 (Deed Restriction and Long-Term Monitoring) consist of an estimated capital cost of $130,000. Annual O&M costs ($247,000) are for the long-term monitoring program. The total 30-year present worth cost of Alternative 2 is $1,679,000.

Costs for Alternative 3 (*In-Situ* Anaerobic Bioremediation) include an estimated $1,000,000 in capital costs which include a treatability study and installation of an injection well system. Annual O&M costs ($468,000) consist of system operation and long-term monitoring. The total 30-year present worth cost of Alternative 3 is estimated to be $3,619,000.

Costs for Alternative 4 (Vacuum-Vaporizer Wells) include an estimated $1,383,000 in capital costs. Capital costs include a pilot study and installation of a series of Vacuum-Vaporizer Wells manifolded into a offgas treatment system. Annual O&M costs ($468,000) consist of system operation and long-term monitoring. The total 30-year present worth cost of Alternative 4 is estimated to be $5,867,000.

Costs for Alternative 5 (*In-Situ* Permeable Reaction Wall) include an estimated $6,285,000 in capital costs. Capital costs include a treatability study and installation of the treatment system comprised of steel sheetpile walls and an *In-Situ* Permeable Reaction Wall. Annual O&M costs ($357,000) consist of periodic reaction wall maintenance/replacement and long-term monitoring. The total 30-year present worth cost of Alternative 5 is estimated to be $9,062,000.

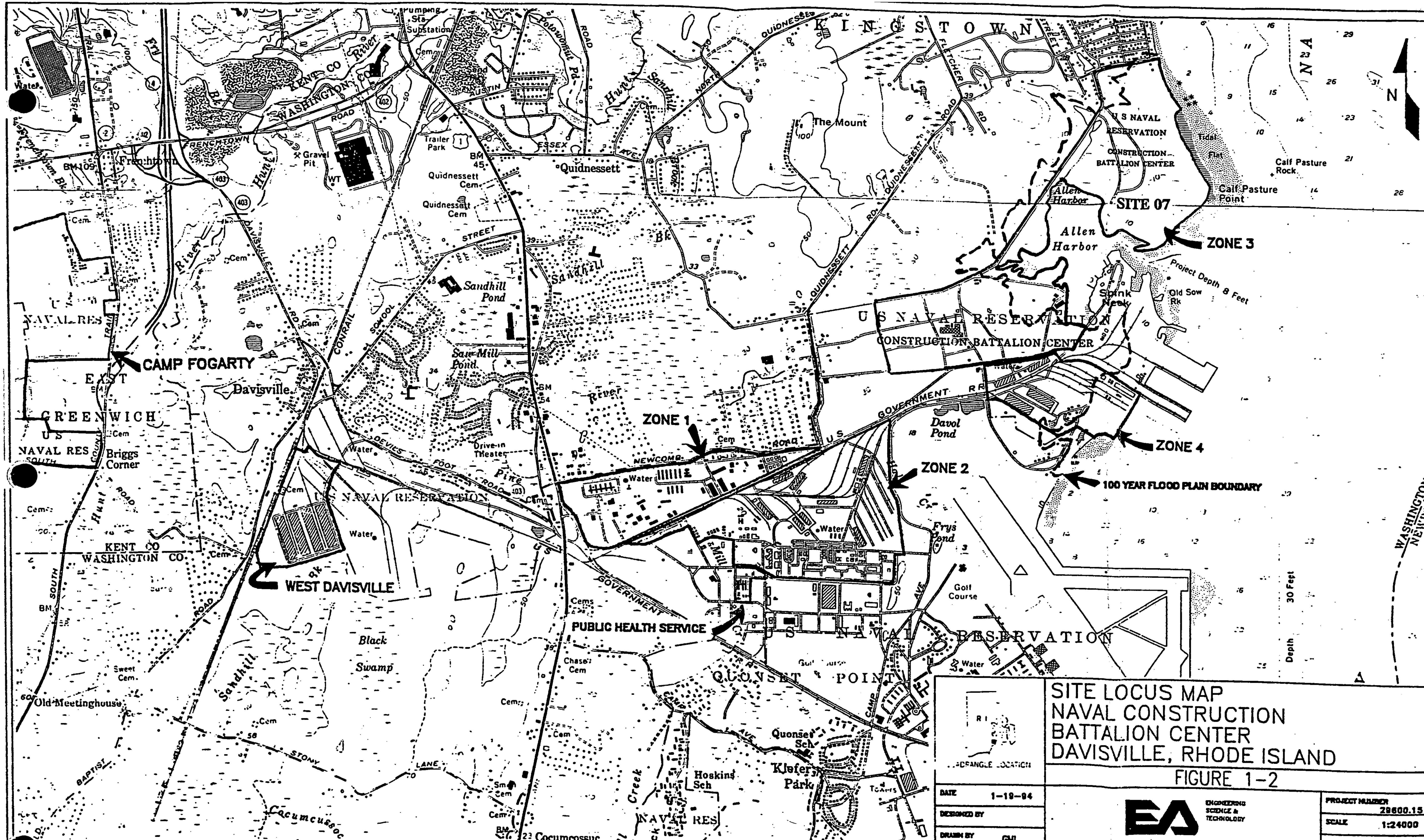


SOURCE: TRC ENVIRONMENTAL(1991)

FILE: F:\PROJECTS\29600.32\3495\CADD\FINAL\FIG1-1.DWG

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	SITE 07 FEASIBILITY STUDY NCBC DAVISVILLE, RHODE ISLAND	AREA MAP NCBC DAVISVILLE

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
JAS	JDR	JMF	JDR	AS SHOWN	7-17-97	29600.32\3495	1-1



SITE LOCUS MAP
NAVAL CONSTRUCTION
BATTALION CENTER
DAVISVILLE, RHODE ISLAND

FIGURE 1-2

BASE MAP: U.S.G.S. EAST GREENWICH AND WICKFORD QUADRANGLE – RHODE ISLAND
7.5 MINUTE SERIES (TOPOGRAPHIC) 1942, PHOTOREVISED 1970 & 1975.

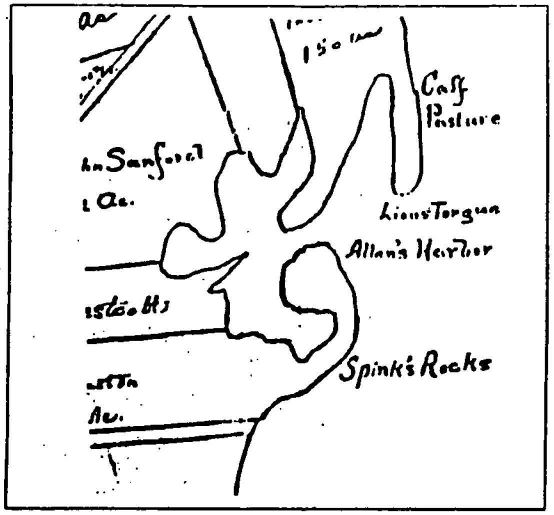
QUADRANGLE LOCATION

DATE	1-19-94
DESIGNED BY	
DRAWN BY	GML
CHECKED BY	GML
PROJECT MANAGER	NAL

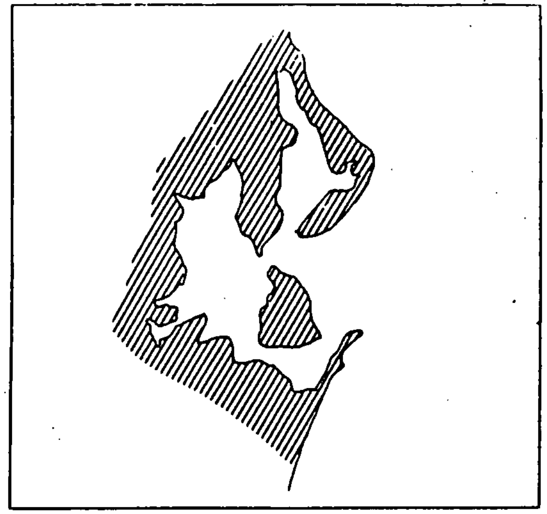
EA ENGINEERING SCIENCE & TECHNOLOGY

SHARON COMMERCE CENTER
2 COMMERCIAL STREET, SUITE 108
SHARON, MASSACHUSETTS 02067
(617) 784-1767

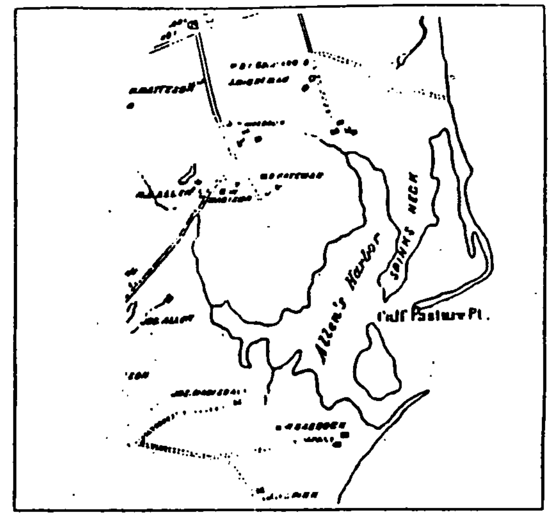
PROJECT NUMBER	29600.15
SCALE	1:24000
FILE NAME	A:DAVTOPO
DRAWING NUMBER	
SHEET NUMBER	



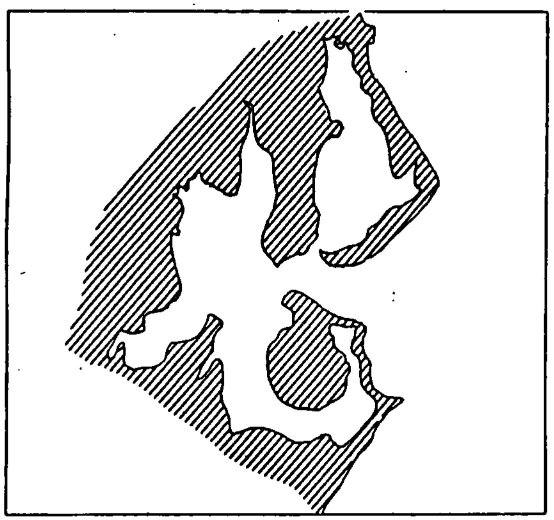
1 CIRCA 1717



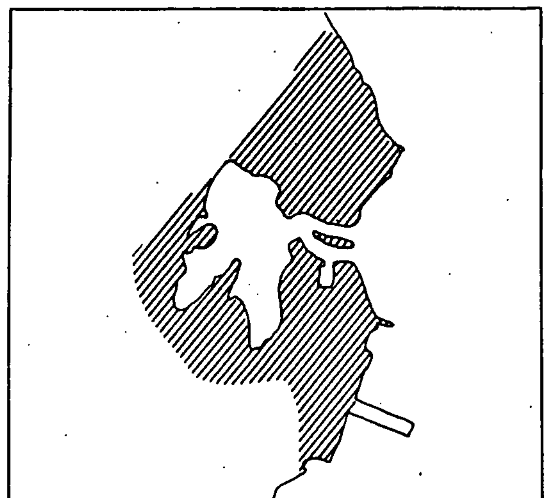
2 CIRCA 1793



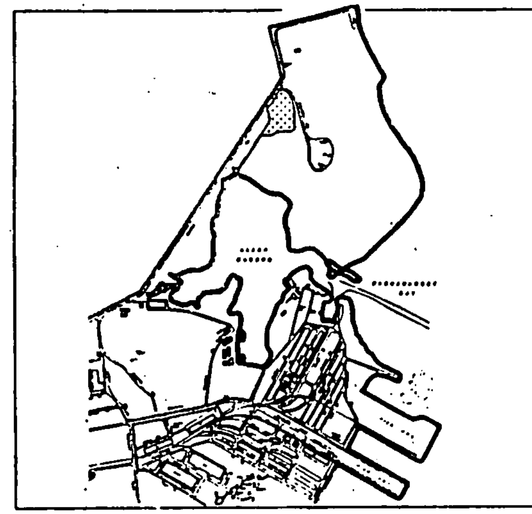
3 CIRCA 1885



4 CIRCA 1939



5 CIRCA 1951

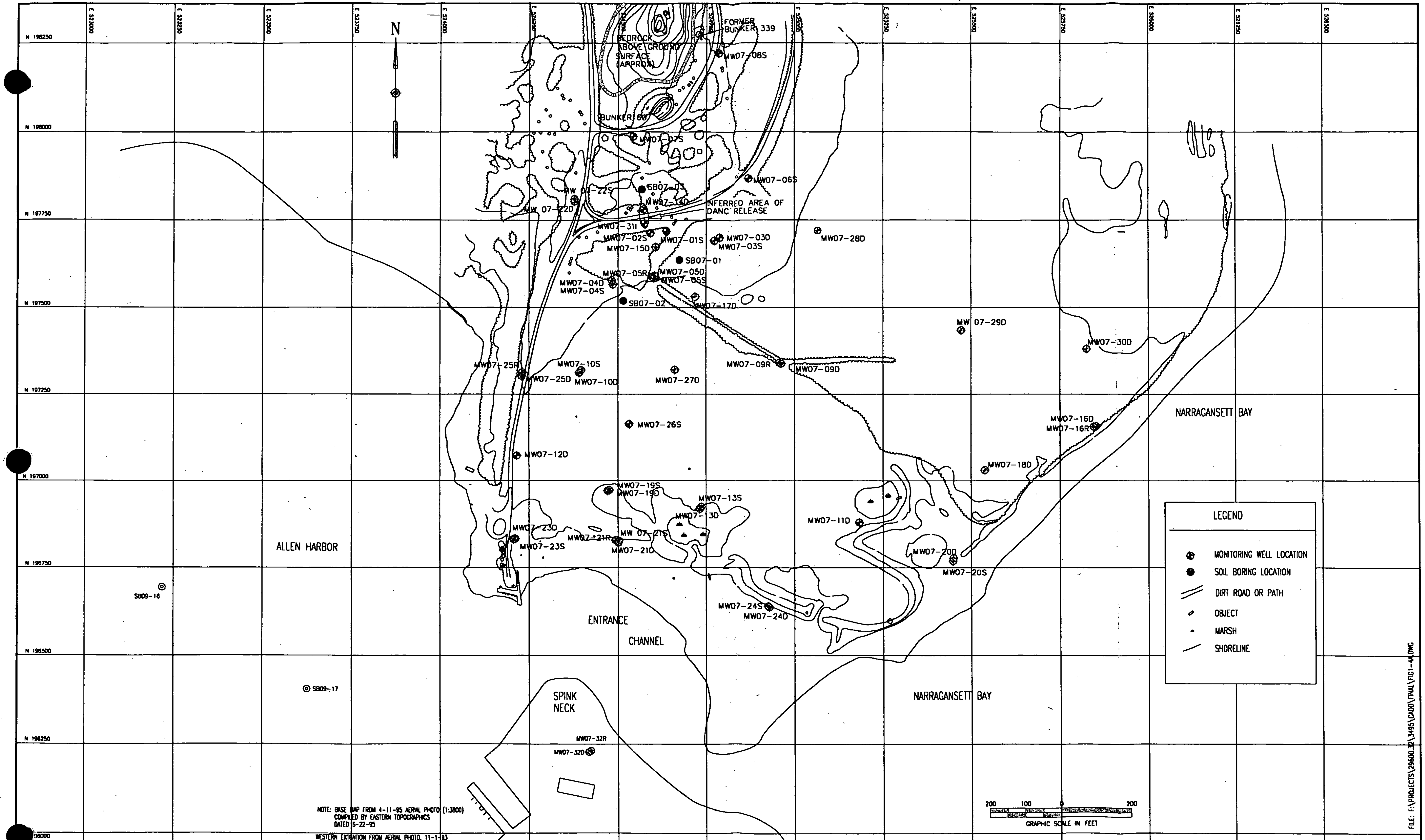


6 CIRCA 1993

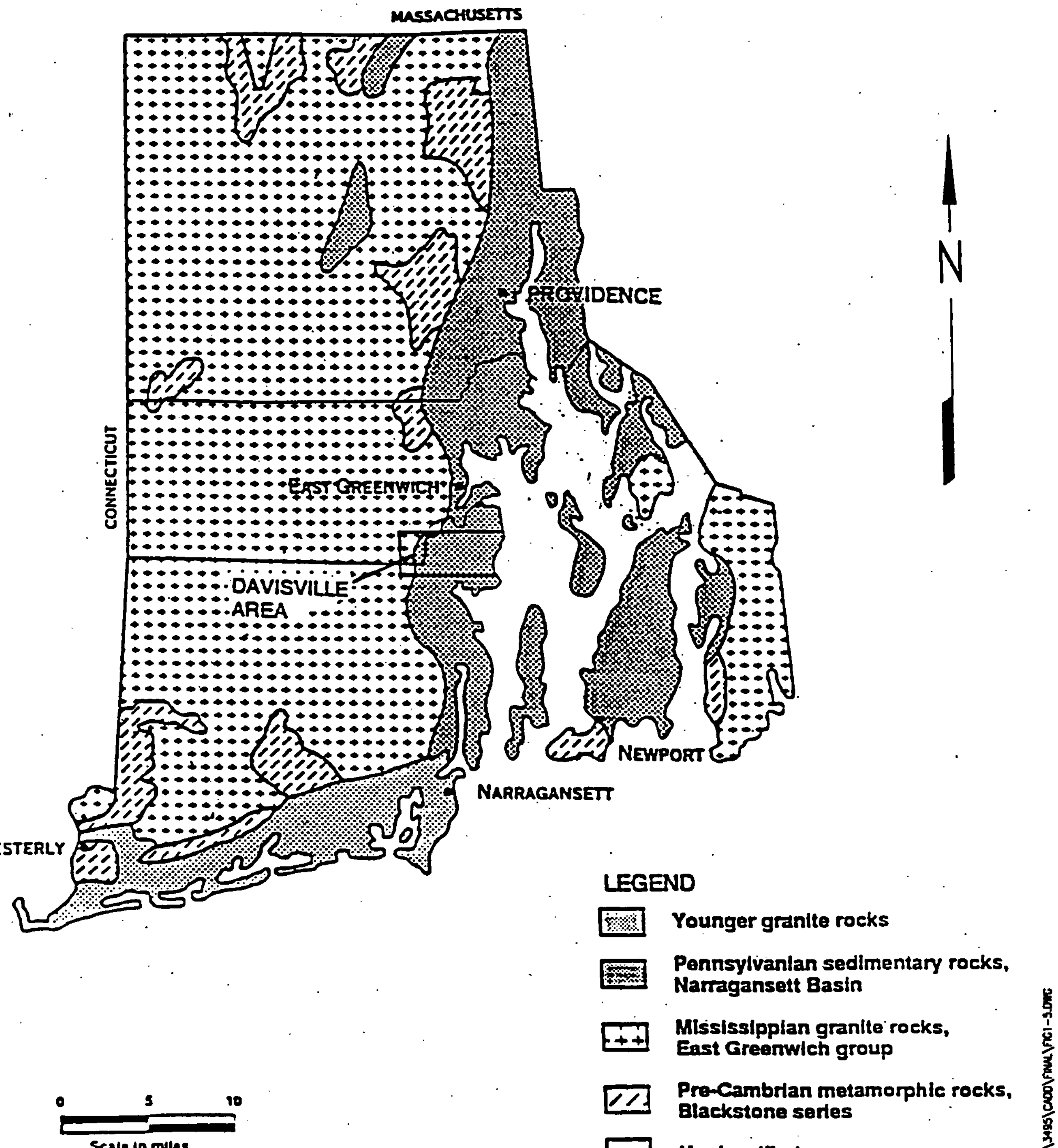
SOURCE: ECOLOGY & ENVIRONMENT, 1994

FILE: F:\PROJECTS\29600.32\3495\CADD\FINAL\FIG1-3.DWG

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	SITE 07 FEASIBILITY STUDY NCBC DAVISVILLE, RHODE ISLAND	HISTORICAL EVOLUTION OF ALLEN HARBOR AREA	DESIGNED BY JDR	DRAWN BY JMF	DATE 7-17-97	PROJECT NO. 29600.32
			CHECKED BY JDR	PROJECT MGR. JAS	SCALE -	FIGURE FIG 1-3



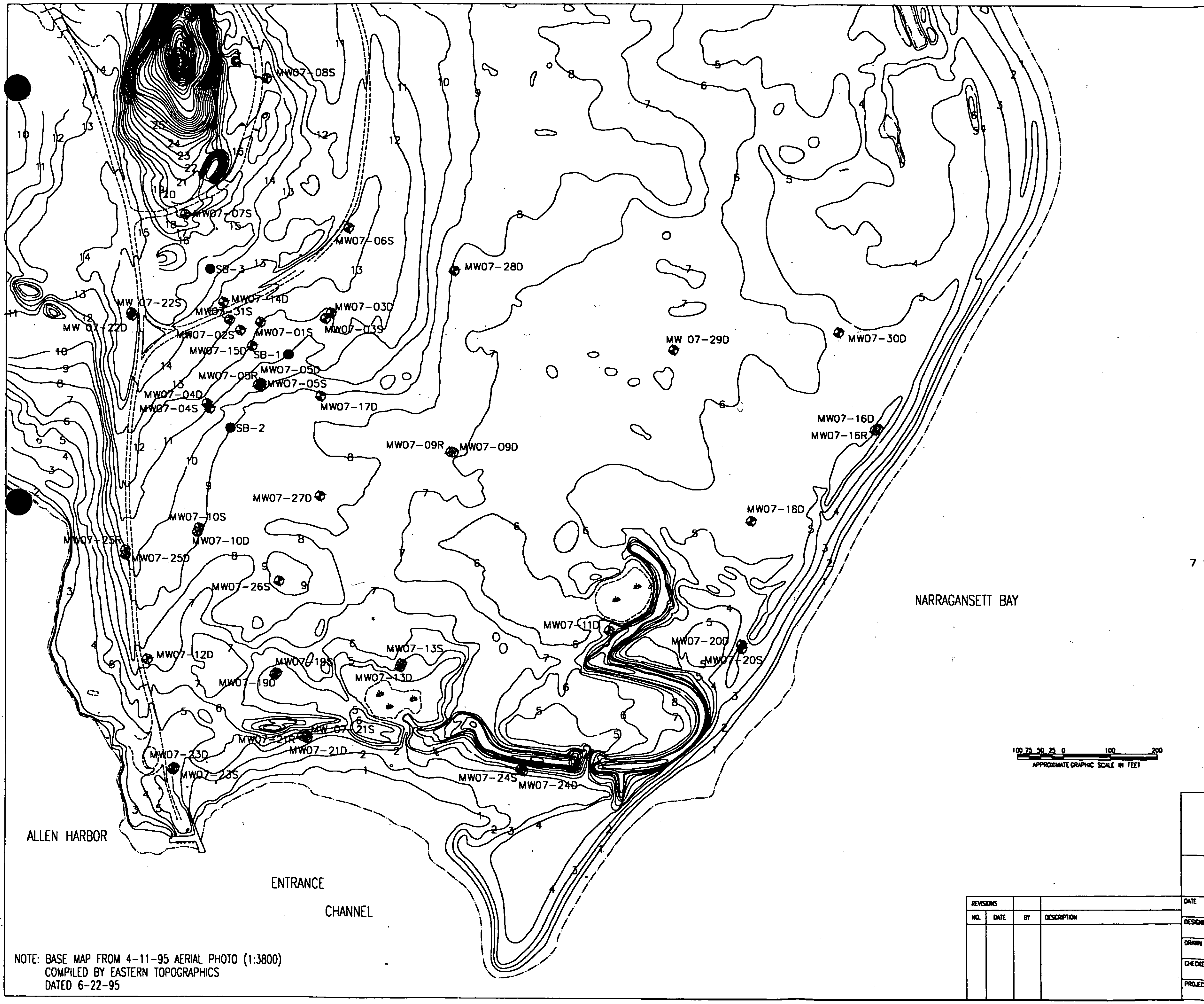
EA ENGINEERING, SCIENCE, AND TECHNOLOGY	DESIGNED BY JAS	DRAWN BY RWC	DATE 4-23-98	PROJECT NO. 29600.32	FILE NAME FIG1-4A	NORTHERN DIVISION CALF PASTURE POINT, IR PROGRAM SITE 07 NCBC DAVISVILLE, RHODE ISLAND	SITE MAP
	CHECKED BY JAS	PROJECT MGR. JAS	SCALE AS SHOWN	DRAWING NO. –	FIGURE 1-4		FIGURE 1-4



SOURCE: TRC, 1994 MODIFIED FROM SOIL SURVEY OF RHODE ISLAND (USDA, 1981)

FILE: F:\PROJECTS\29600.32\3495\CADD\FINAL\FIG1-5.DWG

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.			SITE 07 FEASIBILITY STUDY NCBC DAVISVILLE, RHODE ISLAND		GENERALIZED GEOLOGIC MAP OF RHODE ISLAND		
PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
JAS	JDR	JMF	JDR	AS SHOWN	7-17-97	29600.32\3495	1-5



LEGEND

- SOIL BORING LOCATION
- MONITORING WELL LOCATION
- DIRT ROAD
- OBJECT
- MARSH
- SHORELINE
- 7 GROUND SURFACE TOPOGRAPHIC CONTOUR (FT ABOVE MSL)

NOTE: BASE MAP FROM 4-11-95 AERIAL PHOTO (1:3800)
COMPILED BY EASTERN TOPOGRAPHICS
DATED 6-22-95

F:\PROJECTS\29600.32\3495\CADD\FINAL\FIG1-6.DWG

SITE TOPOGRAPHIC MAP

IR PROGRAM SITE 07, CALF PASTURE POINT

NORTHERN DIVISION
SITE 07 FEASIBILTY STUDY
NCBC DAVISVILLE, RHODE ISLAND

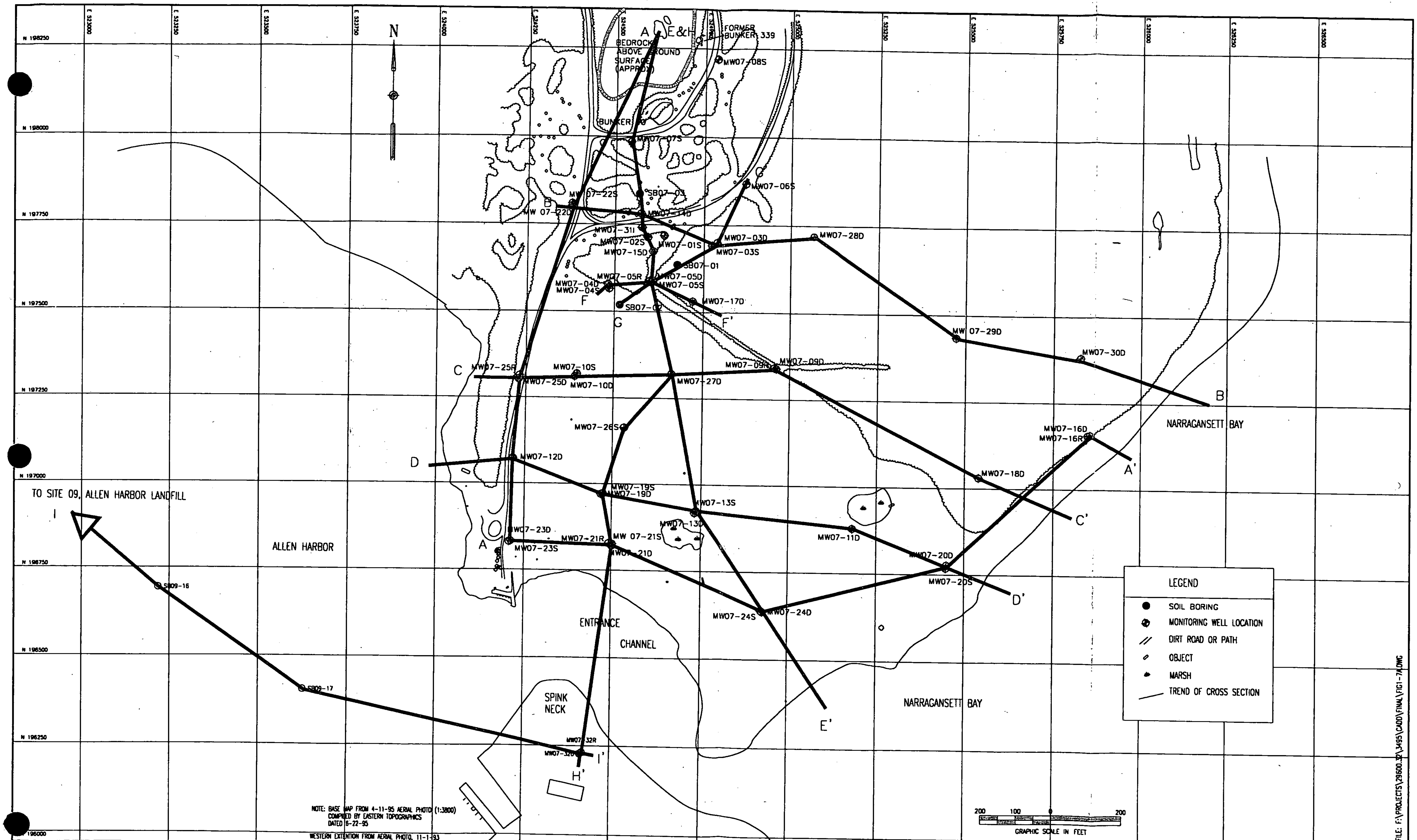
REVISIONS			
NO.	DATE	BY	DESCRIPTION

DATE 4-23-98
DESIGNED BY JDR
DRAWN BY JMF
CHECKED BY JDR
PROJECT MANAGER JAS

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
175 MIDDLESEX TURNPIKE
BEDFORD, MA 01730
781.275.8846

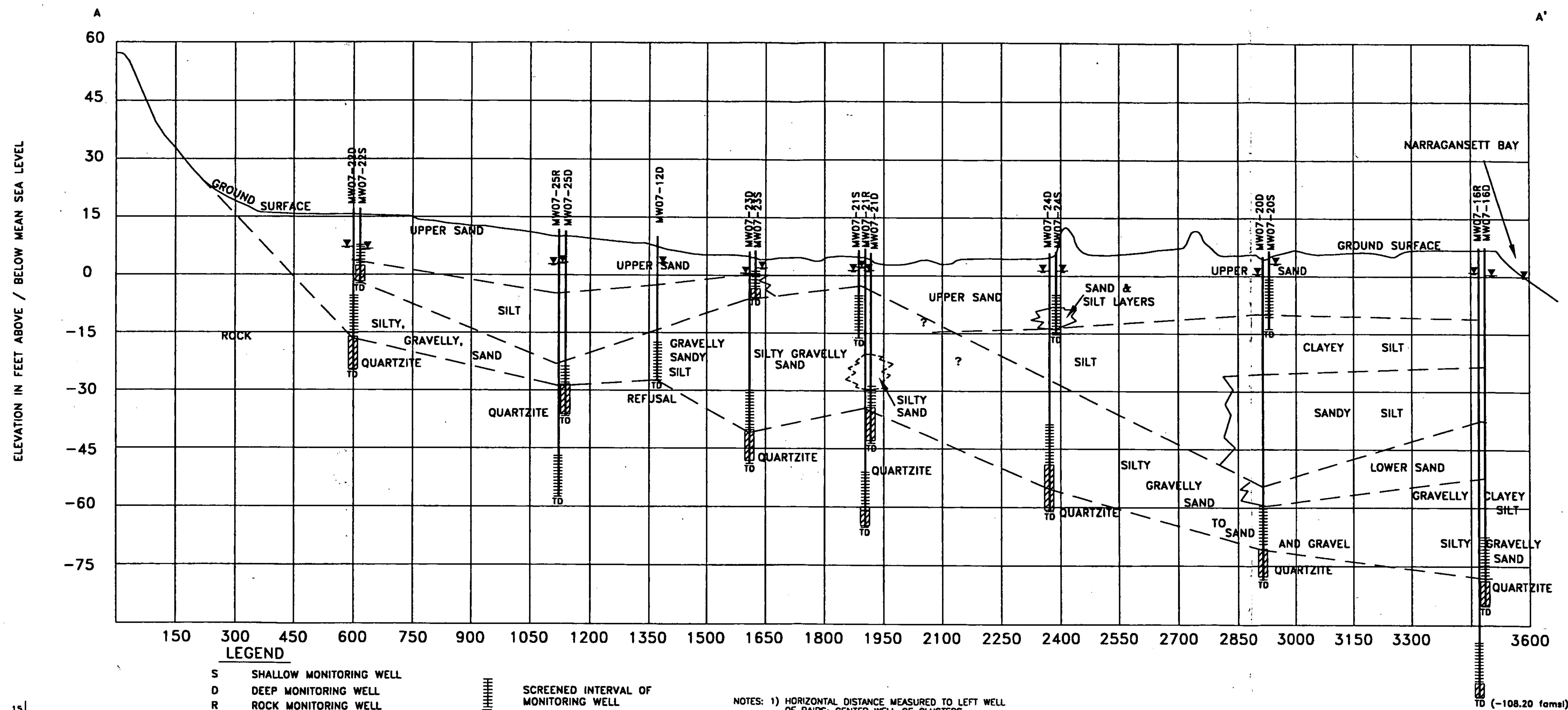
ALASKA, CALIFORNIA, COLORADO, DELAWARE, FLORIDA, GEORGIA, HAWAII, ILLINOIS, MARYLAND, MASSACHUSETTS, NEBRASKA, NEW JERSEY, NEW YORK, NORTH CAROLINA, TEXAS, WASHINGTON

PROJECT NUMBER 29600.32
SCALE AS SHOWN
FILE NAME FIG1-6
LAYER NAME
FIGURE NUMBER 1-6



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	DESIGNED BY JAS	DRAWN BY RWC	DATE 4-23-98	PROJECT NO. 29600.32	FILE NAME FIG1-7A	NORTHERN DIVISION CALF PASTURE POINT, IR PROGRAM SITE 07 NCBC DAVISVILLE, RHODE ISLAND	LOCATION OF GEOLOGIC CROSS SECTIONS
	CHECKED BY JAS	PROJECT MGR. JAS	SCALE AS SHOWN	DRAWING NO. -	FIGURE 1-7		

FIGURE 1-7



LEGEND

S	SHALLOW MONITORING WELL
D	DEEP MONITORING WELL
R	ROCK MONITORING WELL
TD	TOTAL DEPTH
▼	WATER LEVEL (1-17-96 MIDTIDE)
	SCREENED INTERVAL OF MONITORING WELL
	BENTONITE SEALED BOREHOLE

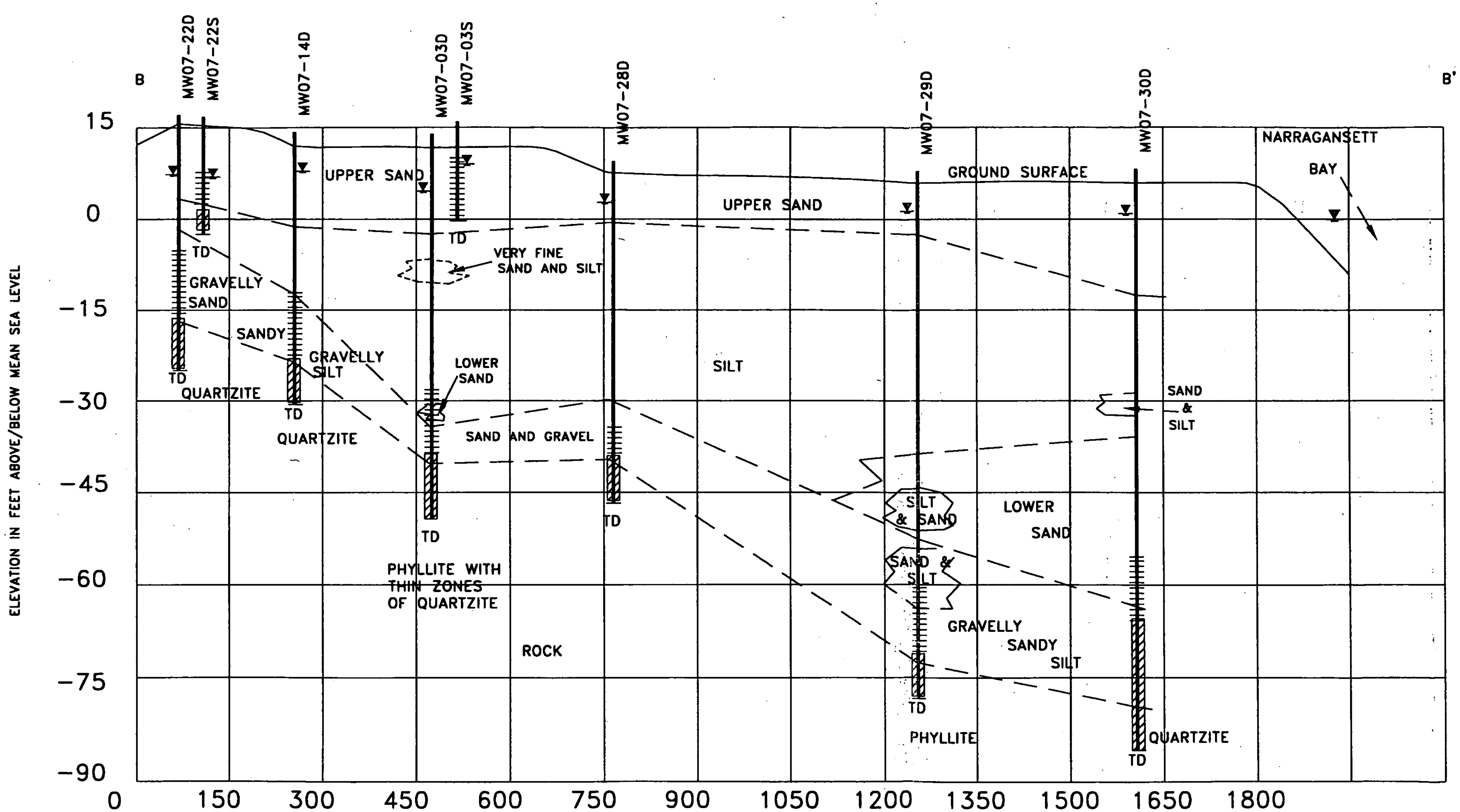
15

0 150

SCALE IN FEET

NOTES:
1) HORIZONTAL DISTANCE MEASURED TO LEFT WELL OF PAIRS; CENTER WELL OF CLUSTERS
2) THE SUBSURFACE SECTIONS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.	DESIGNED BY JLS	DRAWN BY JFW	DATE 7-17-97	PROJECT NO. 29600.32	NORTHERN DIVISION SITE 07 FEASIBILITY STUDY NCBC DAVISVILLE, RHODE ISLAND	GEOLOGIC CROSS SECTION A-A' SITE 07, CALF PASTURE POINT
	CHECKED BY JDR	PROJECT MGR. JAS	SCALE AS SHOWN	LAYER NAME CROSSA-A		FIGURE 1-8

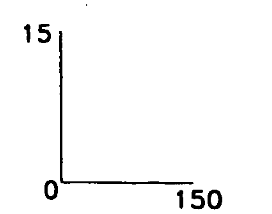


LEGEND

S	SHALLOW MONITORING WELL
D	DEEP MONITORING WELL
R	ROCK MONITORING WELL
TD	TOTAL DEPTH
▼	WATER LEVEL (1-17-96 MIDTIDE)
	SCREENED INTERVAL OF MONITORING WELL
	BENTONITE SEALED BOREHOLE

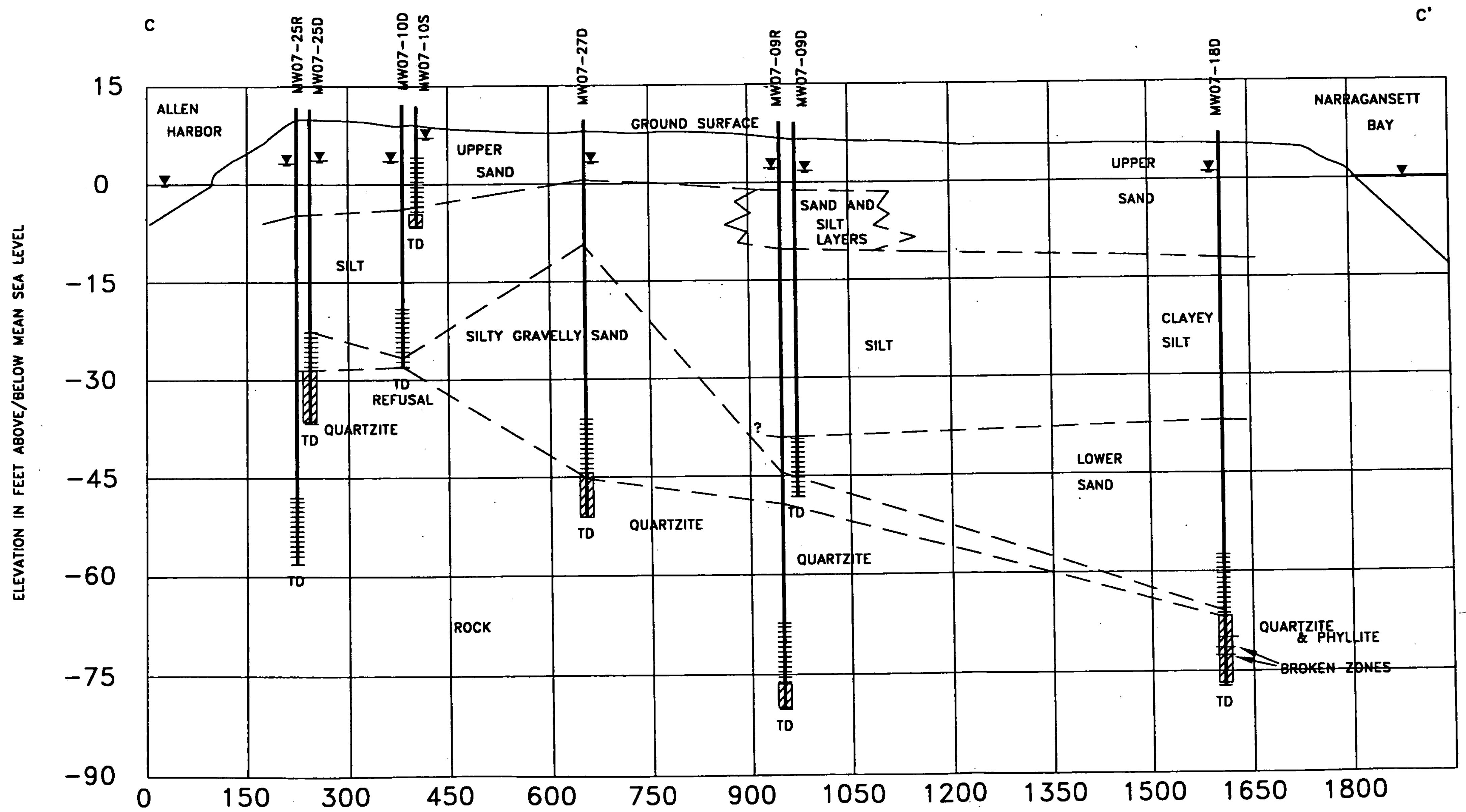
NOTES: 1) HORIZONTAL DISTANCE MEASURED TO LEFT WELL OF PAIRS; CENTER WELL OF CLUSTERS

2) THE SUBSURFACE SECTIONS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.



SCALE IN FEET

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.	DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	NORTHERN DIVISION SITE 07 FEASIBILITY STUDY NCBC DAVISVILLE, RHODE ISLAND	GEOLOGIC CROSS SECTION B-B' IR PROGRAM SITE 07, CALF PASTURE POINT FIGURE 1-9
	JBM	JFW	7-17-97	29600.32		
	CHECKED BY	PROJECT MGR.	SCALE	LAYER NAME		
	JDR	JAS	AS SHOWN	CROSSB-B		

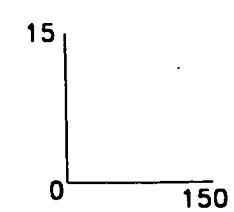


LEGEND

S	SHALLOW MONITORING WELL
D	DEEP MONITORING WELL
R	ROCK MONITORING WELL
TD	TOTAL DEPTH
▼	WATER LEVEL (1-17-96 MIDTIDE)
	SCREENED INTERVAL OF MONITORING WELL
	BENTONITE SEALED BOREHOLE

NOTES: 1) HORIZONTAL DISTANCE MEASURED TO LEFT WELL OF PAIRS; CENTER WELL OF CLUSTERS

2) THE SUBSURFACE SECTIONS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.



SCALE IN FEET

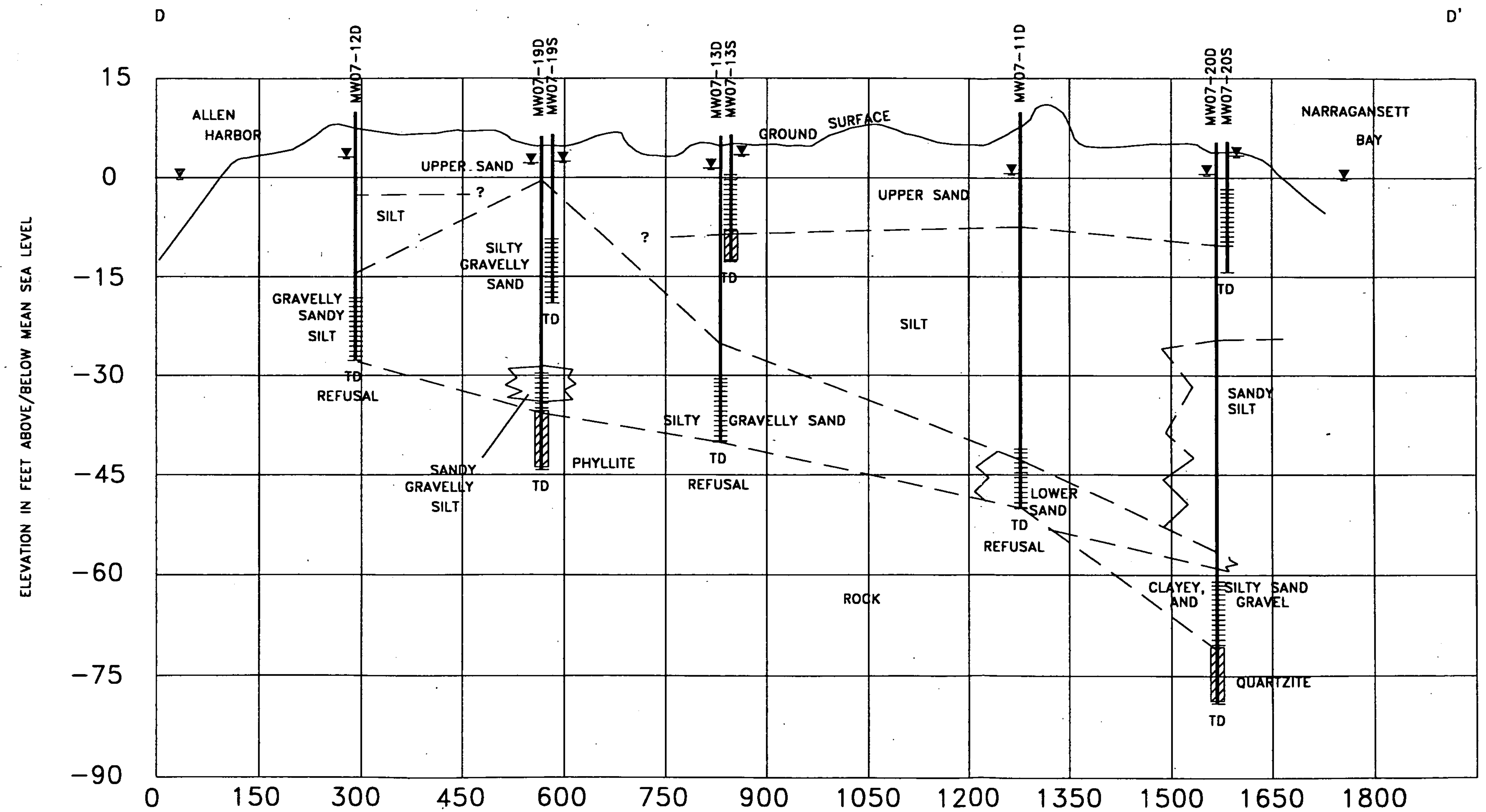
EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.
JLS	JFW	7-17-97	29600.32
CHECKED BY	PROJECT MGR.	SCALE	LAYER NAME
JDR	JAS	AS SHOWN	CROSSC-C

NORTHERN DIVISION
SITE 07 FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

GEOLOGIC CROSS SECTION C-C'
SITE 07, CALF PASTURE POINT

FIGURE 1-10



LEGEND

S	SHALLOW MONITORING WELL
D	DEEP MONITORING WELL
R	ROCK MONITORING WELL
TD	TOTAL DEPTH
▼	WATER LEVEL (1-17-96 MIDTIDE)
	SCREENED INTERVAL OF MONITORING WELL
	BENTONITE SEALED BOREHOLE

NOTES: 1) HORIZONTAL DISTANCE MEASURED TO LEFT WELL OF PAIRS; CENTER WELL OF CLUSTERS
2) THE SUBSURFACE SECTIONS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.

15

0 150

SCALE IN FEET

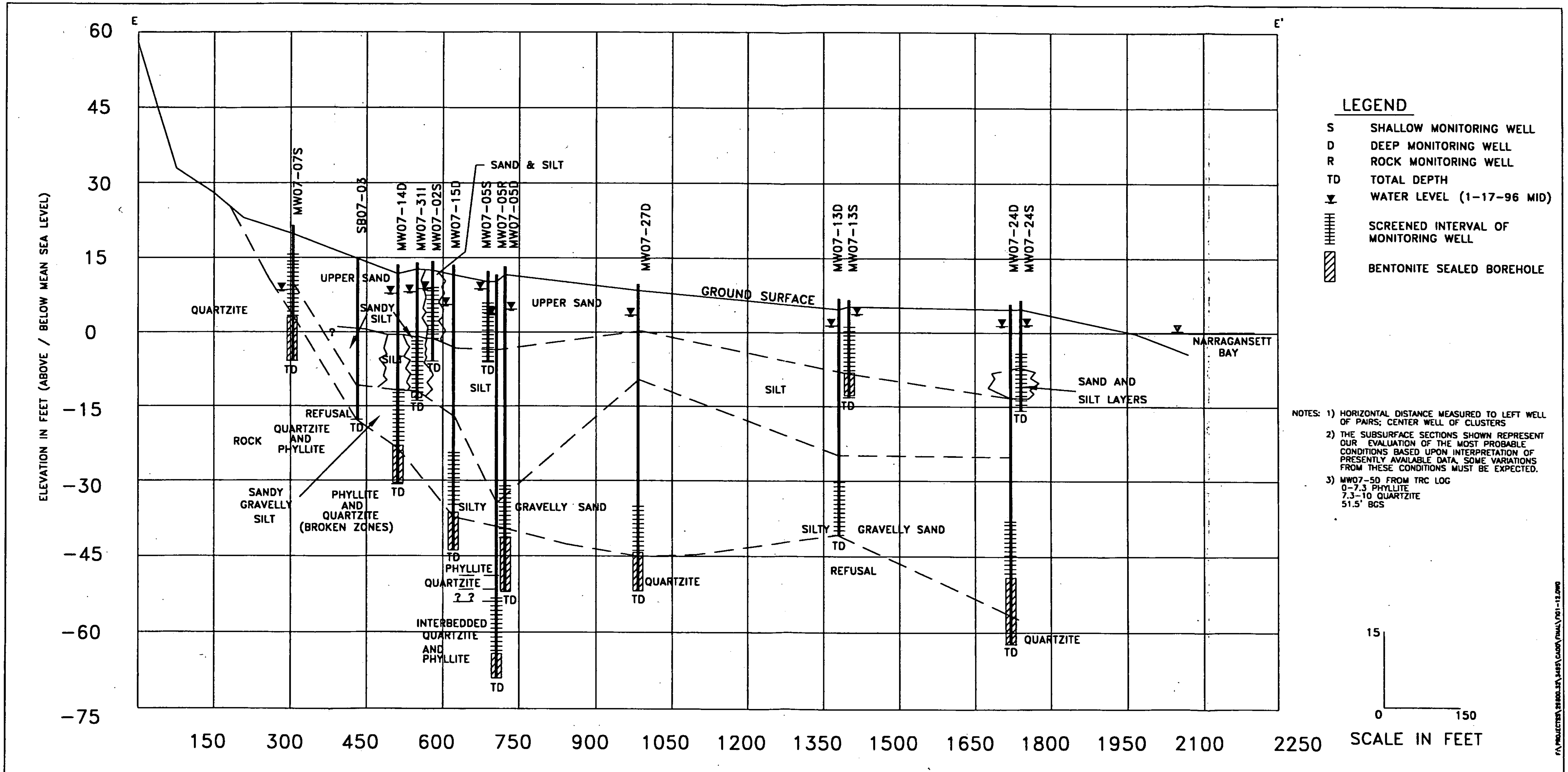
EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.
JLS	JFW	9-9-98	29600.32
CHECKED BY	PROJECT MGR.	SCALE	LAYER NAME
JDR	JAS	AS SHOWN	CROSSD-D

NORTHERN DIVISION
SITE 07 FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

GEOLOGIC CROSS SECTION D-D'
SITE 07, CALF PASTURE POINT

FIGURE 1-11

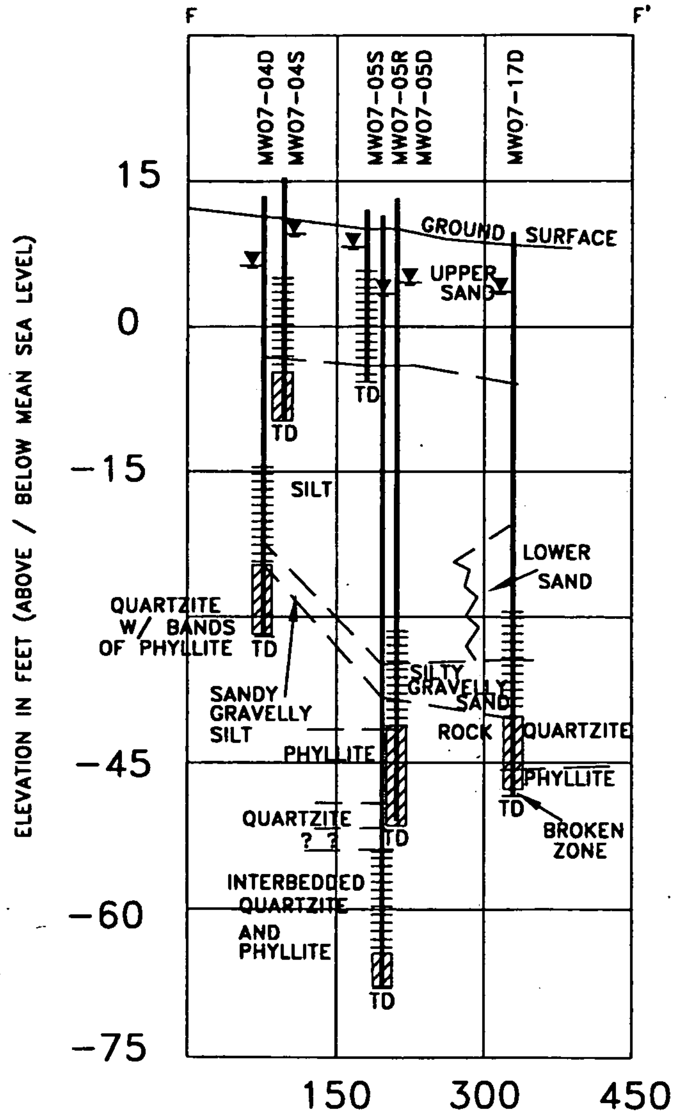


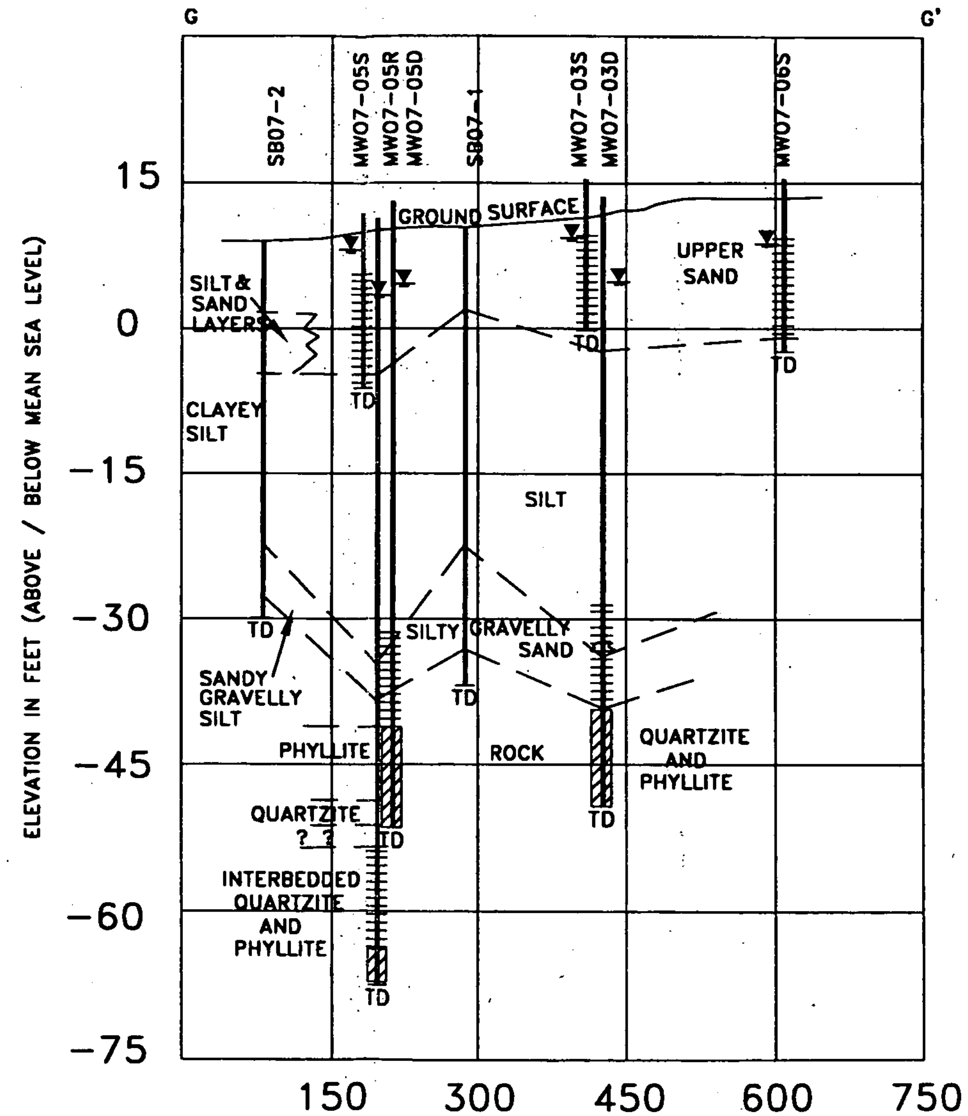
EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.
JLS	JFW	7-17-97	29600.32
CHECKED BY	PROJECT MGR.	SCALE	LAYER NAME
JDR	JAS	AS SHOWN	CROSSE-E

NORTHERN DIVISION
SITE 07 FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

GEOLOGIC CROSS SECTION E-E'
SITE 07, CALF PASTURE POINT
FIGURE 1-12

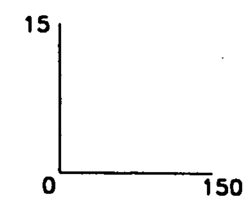




LEGEND

S SHALLOW MONITORING WELL
D DEEP MONITORING WELL
R ROCK MONITORING WELL
TD TOTAL DEPTH
WATER LEVEL
SCREENED INTERVAL OF MONITORING WELL
BENTONITE SEALED BOREHOLE

NOTES:
1) HORIZONTAL DISTANCE MEASURED TO LEFT WELL OF PAIRS; CENTER WELL OF CLUSTERS
2) THE SUBSURFACE SECTIONS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA, SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.
5) SOIL BORINGS AT SITE 07 WERE BACKFILLED WITH CEMENT/ BENTONITE GROUT FROM TOTAL DEPTH TO LAND SURFACE.
4) MW07-5D FROM TRC LOG
0-7.3 PHYLLITE
7.3-10 QUARTZITE
51.5' BGS



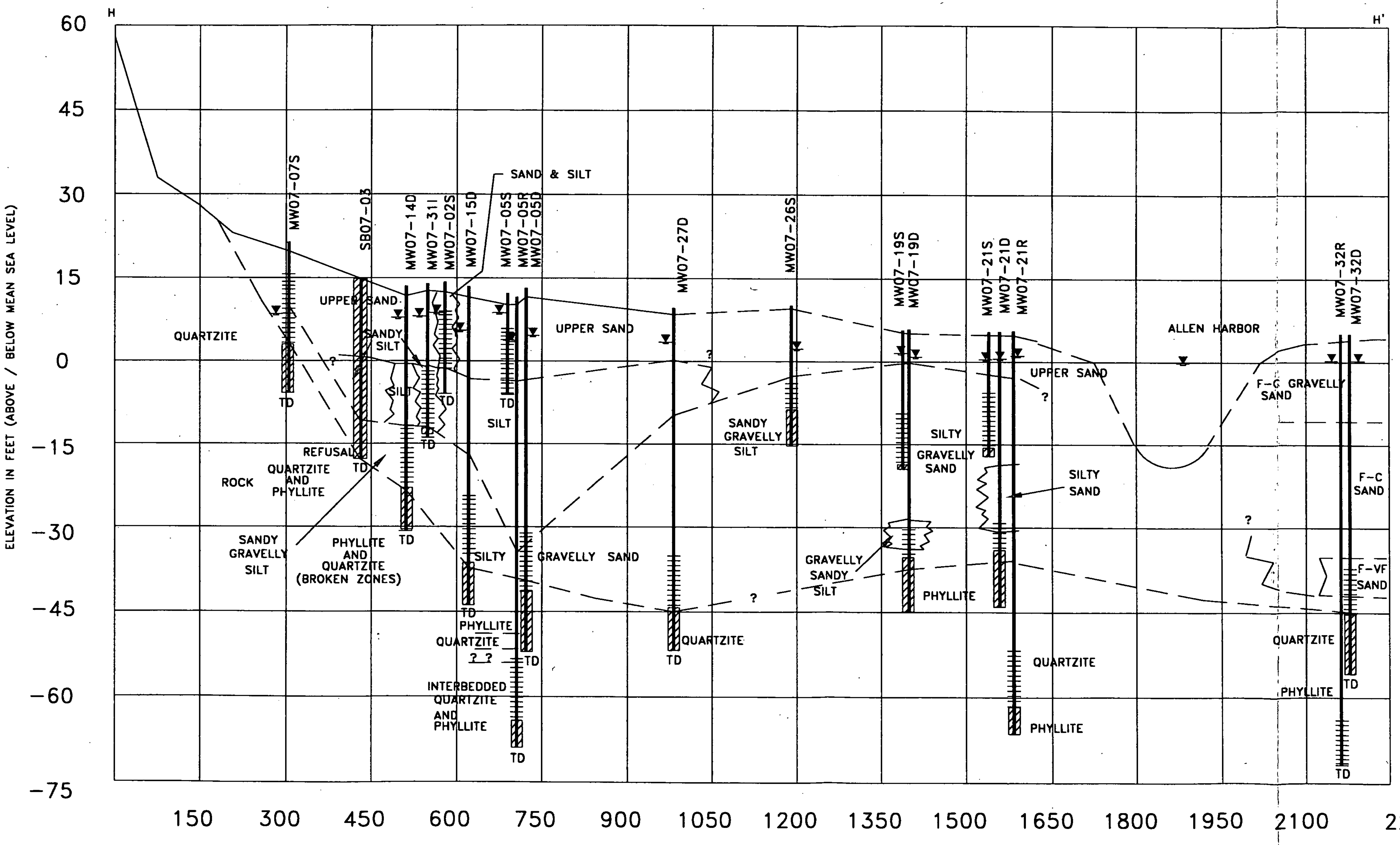
SCALE IN FEET

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.
JLS	JFW	7-17-97	29600.32
CHECKED BY	PROJECT MGR.	SCALE	LAYER NAME
JDR	JAS	AS SHOWN	CROSSF-G

NORTHERN DIVISION
SITE 07 FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

GEOLOGIC CROSS SECTIONS F-F' & G-G'
SITE 07, CALF PASTURE POINT
FIGURE 1-13



LEGEND

- S SHALLOW MONITORING WELL
- D DEEP MONITORING WELL
- R ROCK MONITORING WELL
- TD TOTAL DEPTH
- WATER LEVEL* (1-17-96 MID)
- SCREENED INTERVAL OF MONITORING WELL
- BENTONITE SEALED BOREHOLE

NOTES:
1) HORIZONTAL DISTANCE MEASURED TO LEFT WELL OF PAIRS; CENTER WELL OF CLUSTERS
2) THE SUBSURFACE SECTIONS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA, SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.
3) MW07-5D FROM TRC LOG
0-7.3 PHYLLITE
7.3-10 QUARTZITE
51.5' BGS

* 9-2-98 LOW FOR MW07-32D/R

15

0 150

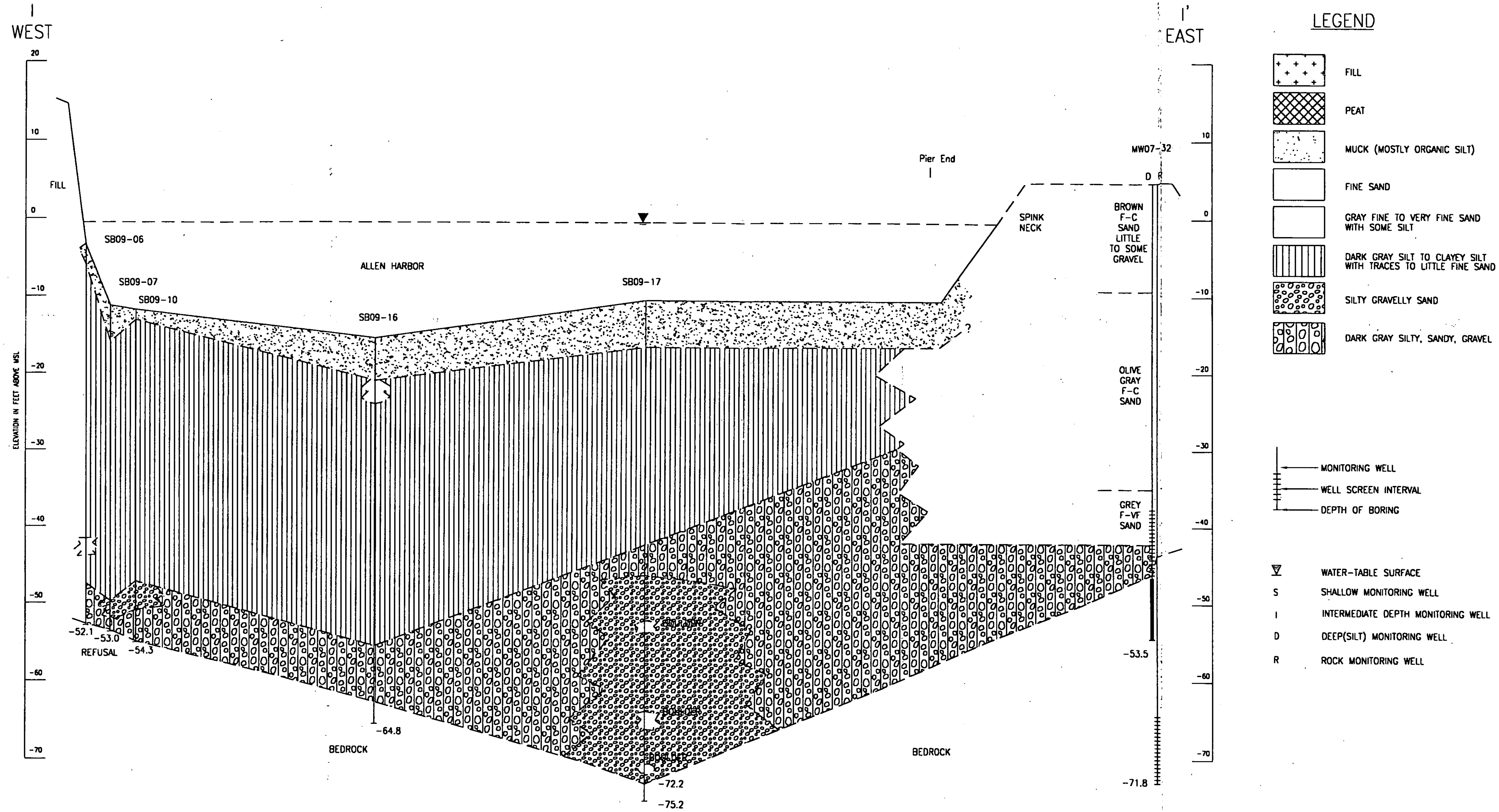
SCALE IN FEET

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.
JLS	JFW	9-9-98	29600.32
CHECKED BY	PROJECT MGR.	SCALE	LAYER NAME
JAS	JAS	AS SHOWN	CROSSH-H

NORTHERN DIVISION
SITE 07 FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

GEOLOGIC CROSS SECTION H-H'
IR PROGRAM SITE 07, CALF PASTURE POINT
FIGURE 1-14a

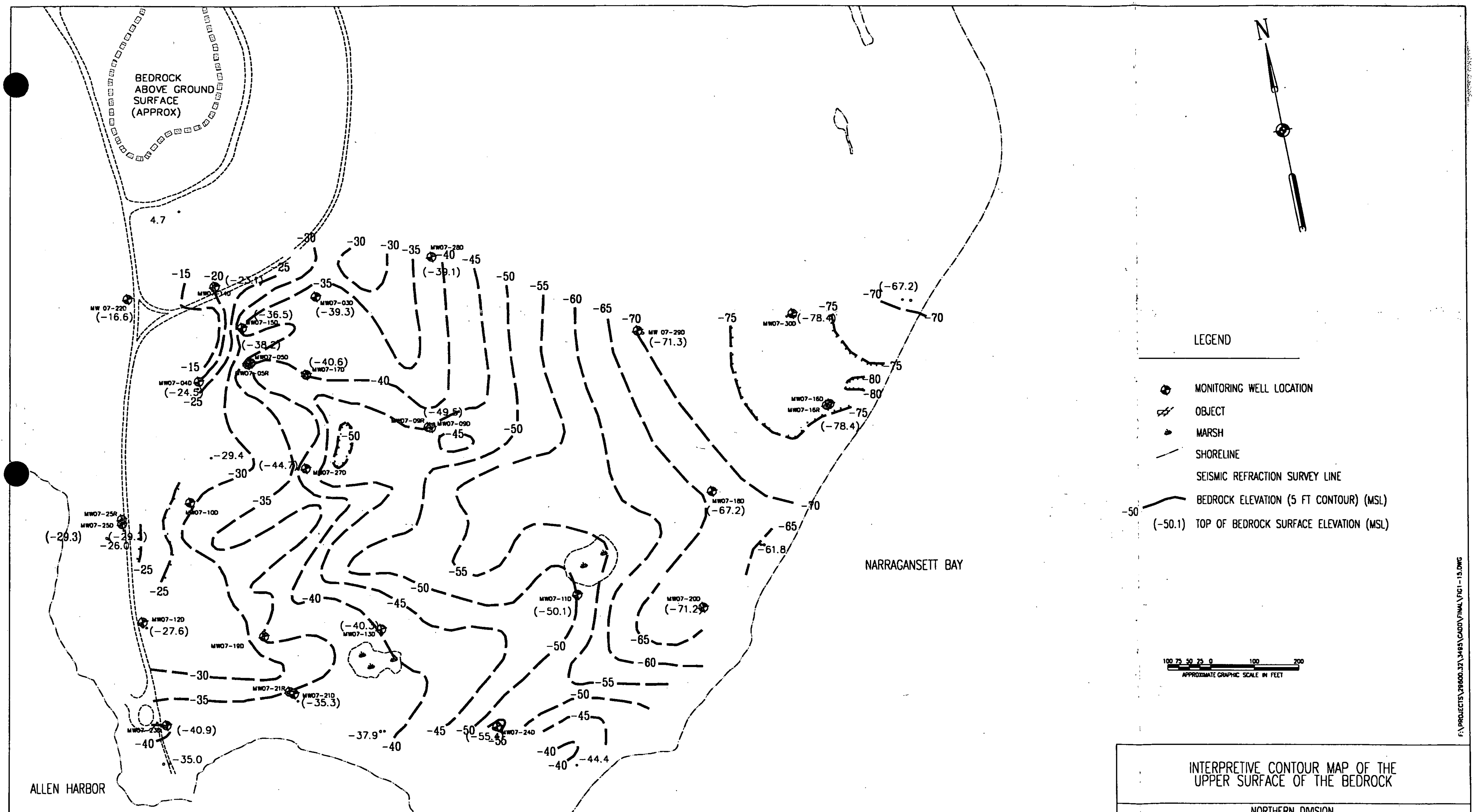


NOTE:
THE SUBSURFACE SECTIONS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.

HORIZONTAL SCALE: 1"=200'

FILE: F:\PROJECTS\29600.32\3495\CADD\FINAL\FIG1-14B.DWG

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	NORTHERN DIVISION CALF PASTURE POINT, IR PROGRAM SITE NCBC DAVISVILLE, RHODE ISLAND	GEOLOGICAL CROSS SECTION I-I'	DESIGNED BY JAS	DRAWN BY MSM/FDV	DATE 4-23-98	PROJECT NO. 29600.32	FILE NAME FIG1-14B
			CHECKED BY JAS	PROJECT MGR. JAS	SCALE AS SHOWN	DRAWING NO. -	FIGURE 1-14b



NOTES: 1) BASE MAP FROM 4-11-95 AERIAL PHOTO (1:3800) COMPILED BY EASTERN TOPOGRAPHICS DATED 6-22-95

2) SEISMIC DATA PROVIDED BY GEOPHYSICAL APPLICATIONS,INC

3) BEDROCK SURFACE CONTOURS BASED UPON INTERPRETIVE DATA ALONG THE SEISMIC REFRACTION SURVEY LINES AND ELEVATIONS OF THE BEDROCK SURFACE ENCOUNTERED AT VARIOUS BORINGS/WELLS.

F:\PROJECTS\29600.32\3493\CADD\FINAL\FIG1-15.DWG

INTERPRETIVE CONTOUR MAP OF THE UPPER SURFACE OF THE BEDROCK

NORTHERN DIVISION
SITE 07 FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

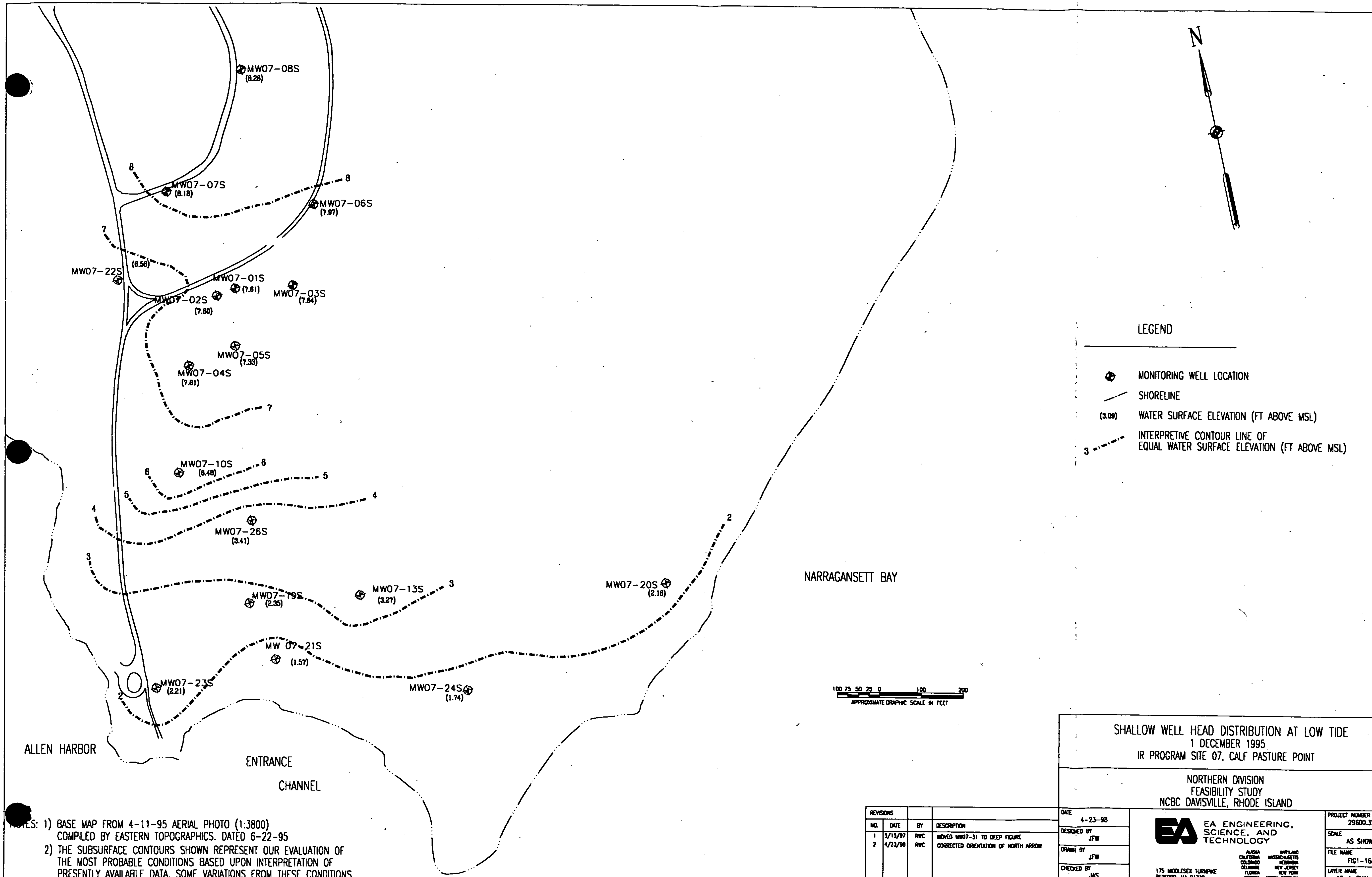
REVISIONS			
NO.	DATE	BY	DESCRIPTION

DATE	AUGUST 1997
DESIGNED BY	JDR
DRAWN BY	JFW
CHECKED BY	JDR
PROJECT MANAGER	JAS

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

175 MIDDLESEX TURNPIKE
BEDFORD, MA 01730
(617) 275-8846

PROJECT NUMBER	29600.32
SCALE	AS SHOWN
FILE NAME	FIG1-15
LAYER NAME	
FIGURE NUMBER	1-15



LEGEND

(symbol)	MONITORING WELL LOCATION
(line)	SHORELINE
(3.09)	WATER SURFACE ELEVATION (FT ABOVE MSL)
3	INTERPRETIVE CONTOUR LINE OF EQUAL WATER SURFACE ELEVATION (FT ABOVE MSL)

NOTES: 1) BASE MAP FROM 4-11-95 AERIAL PHOTO (1:3800) COMPILED BY EASTERN TOPOGRAPHICS. DATED 6-22-95

2) THE SUBSURFACE CONTOURS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.

SHALLOW WELL HEAD DISTRIBUTION AT LOW TIDE
1 DECEMBER 1995
IR PROGRAM SITE 07, CALF PASTURE POINT

NORTHERN DIVISION
FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

REVISIONS

NO.	DATE	BY	DESCRIPTION
1	5/15/97	RWC	MOVED MW07-31 TO DEEP FIGURE
2	4/23/98	RWC	CORRECTED ORIENTATION OF NORTH ARROW

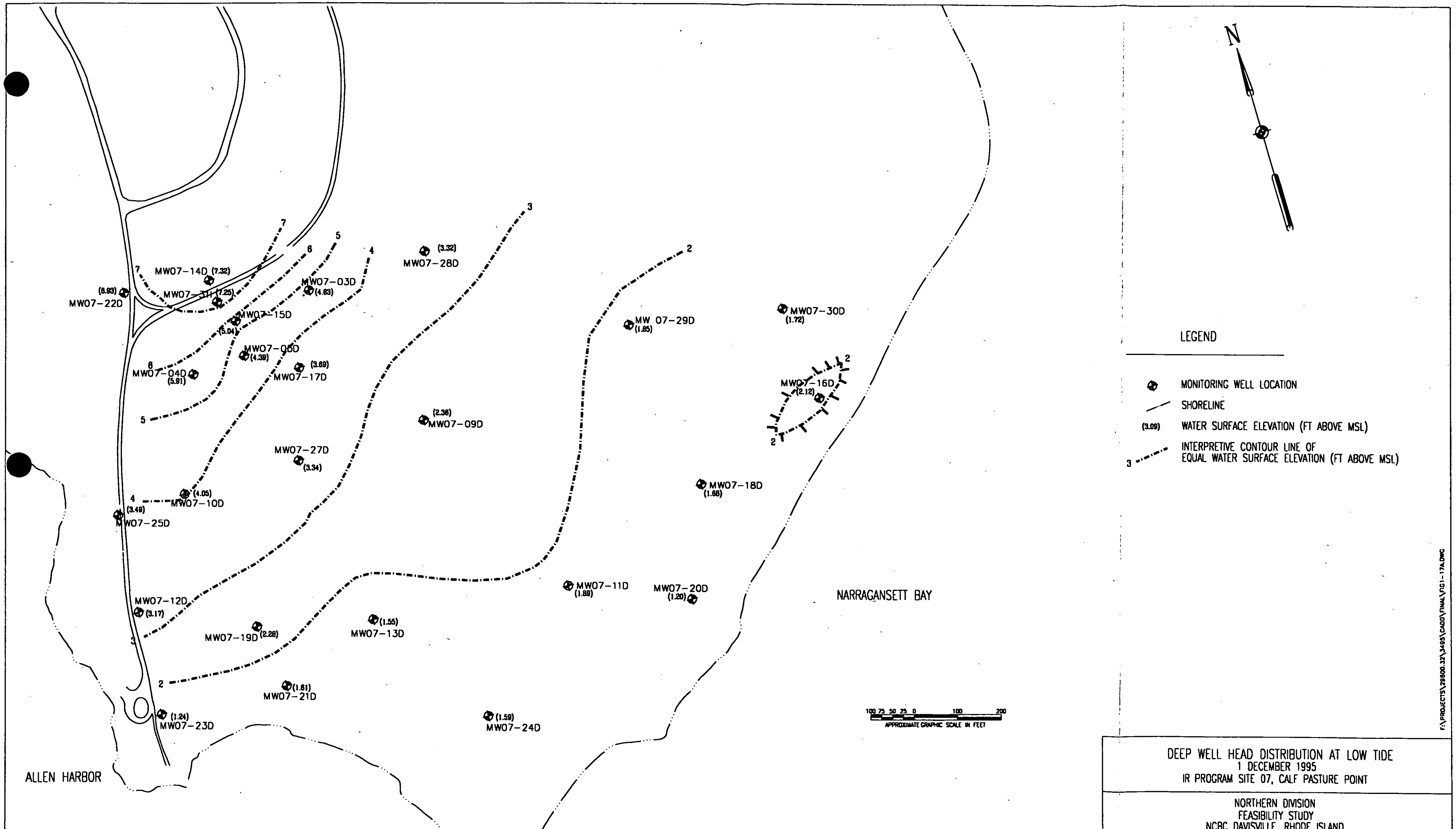
DATE 4-23-98
DESIGNED BY JFW
DRAWN BY JFW
CHECKED BY JAS
PROJECT MANAGER JAS

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
175 MIDDLESEX TURNPIKE
BEDFORD, MA 01730
781.275.8846

ALASKA, CALIFORNIA, COLORADO, DELAWARE, FLORIDA, GEORGIA, HAWAII, ILLINOIS, MARYLAND, MASSACHUSETTS, NEBRASKA, NEW JERSEY, NEW YORK, NORTH CAROLINA, TEXAS, WASHINGTON

PROJECT NUMBER 29600.32
SCALE AS SHOWN
FILE NAME FIG1-16A
LAYER NAME 12-1-SHAL-LOW
FIGURE NUMBER 1-16

F:\PROJECTS\29600.32\3495\CADD\FINAL\1-16A.DWG



NOTES: 1) BASE MAP FROM 4-11-95 AERIAL PHOTO (1:3800) COMPILED BY EASTERN TOPOGRAPHICS. DATED 6-22-95

2) THE SUBSURFACE CONTOURS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.

DEEP WELL HEAD DISTRIBUTION AT LOW TIDE
1 DECEMBER 1995
IR PROGRAM SITE 07, CALF PASTURE POINT

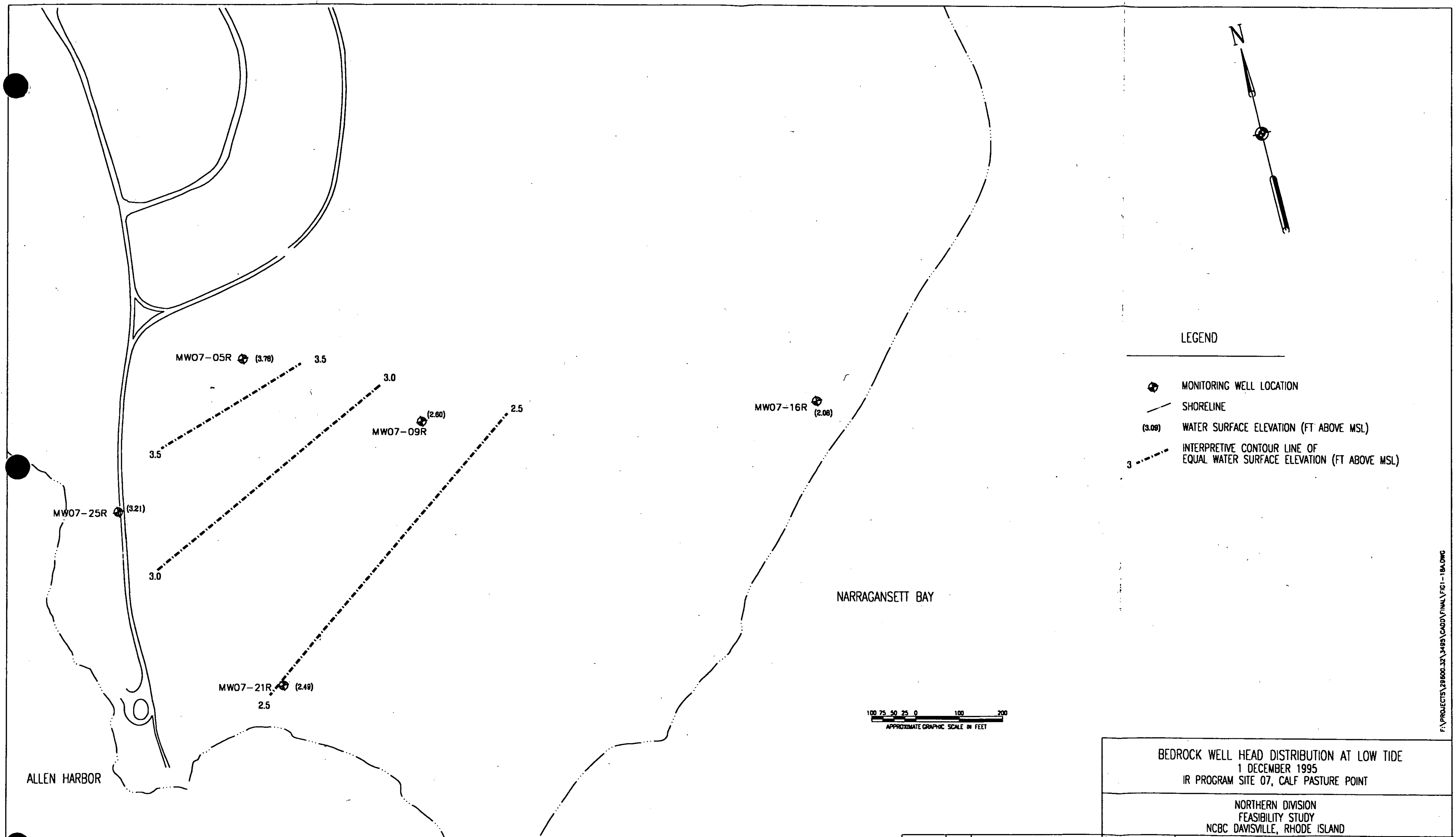
NORTHERN DIVISION
FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

REVISIONS			
NO.	DATE	BY	DESCRIPTION
1	5/29/97	RWC	ADDED MW07-31I, ADJUSTED 7 FT CONTOUR
2	4/23/98	RWC	CORRECTED ORIENTATION OF NORTH ARROW

DATE 4-23-98
DESIGNED BY JFW
DRAWN BY JFW
CHECKED BY JAS
PROJECT MANAGER JAS

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
175 MIDDLESEX TURNPIKE
BEDFORD, MA 01730
781.275.8846
ALASKA MARYLAND CALIFORNIA MASSACHUSETTS COLORADO NEBRASKA DELAWARE NEW JERSEY FLORIDA NEW YORK GEORGIA NORTH CAROLINA HAWAII TEXAS ILLINOIS WASHINGTON

PROJECT NUMBER 29600.32
SCALE AS SHOWN
FILE NAME FIG1-17A
LAYER NAME 12-1-DEEP-LOW
FIGURE NUMBER 1-17



NOTES: 1) BASE MAP FROM 4-11-95 AERIAL PHOTO (1:3800) COMPILED BY EASTERN TOPOGRAPHICS. DATED 6-22-95

2) THE SUBSURFACE CONTOURS SHOWN REPRESENT OUR EVALUATION OF THE MOST PROBABLE CONDITIONS BASED UPON INTERPRETATION OF PRESENTLY AVAILABLE DATA. SOME VARIATIONS FROM THESE CONDITIONS MUST BE EXPECTED.

BEDROCK WELL HEAD DISTRIBUTION AT LOW TIDE
1 DECEMBER 1995
IR PROGRAM SITE 07, CALF PASTURE POINT

NORTHERN DIVISION
FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

REVISIONS			
NO.	DATE	BY	DESCRIPTION
1	4/23/98	RWC	CORRECTED ORIENTATION OF NORTH ARROW

DATE 4-23-98
DESIGNED BY JFW
DRAWN BY JFW
CHECKED BY JAS
PROJECT MANAGER JAS

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
175 MIDDLESEX TURNPIKE
BEDFORD, MA 01730
781.275.8846

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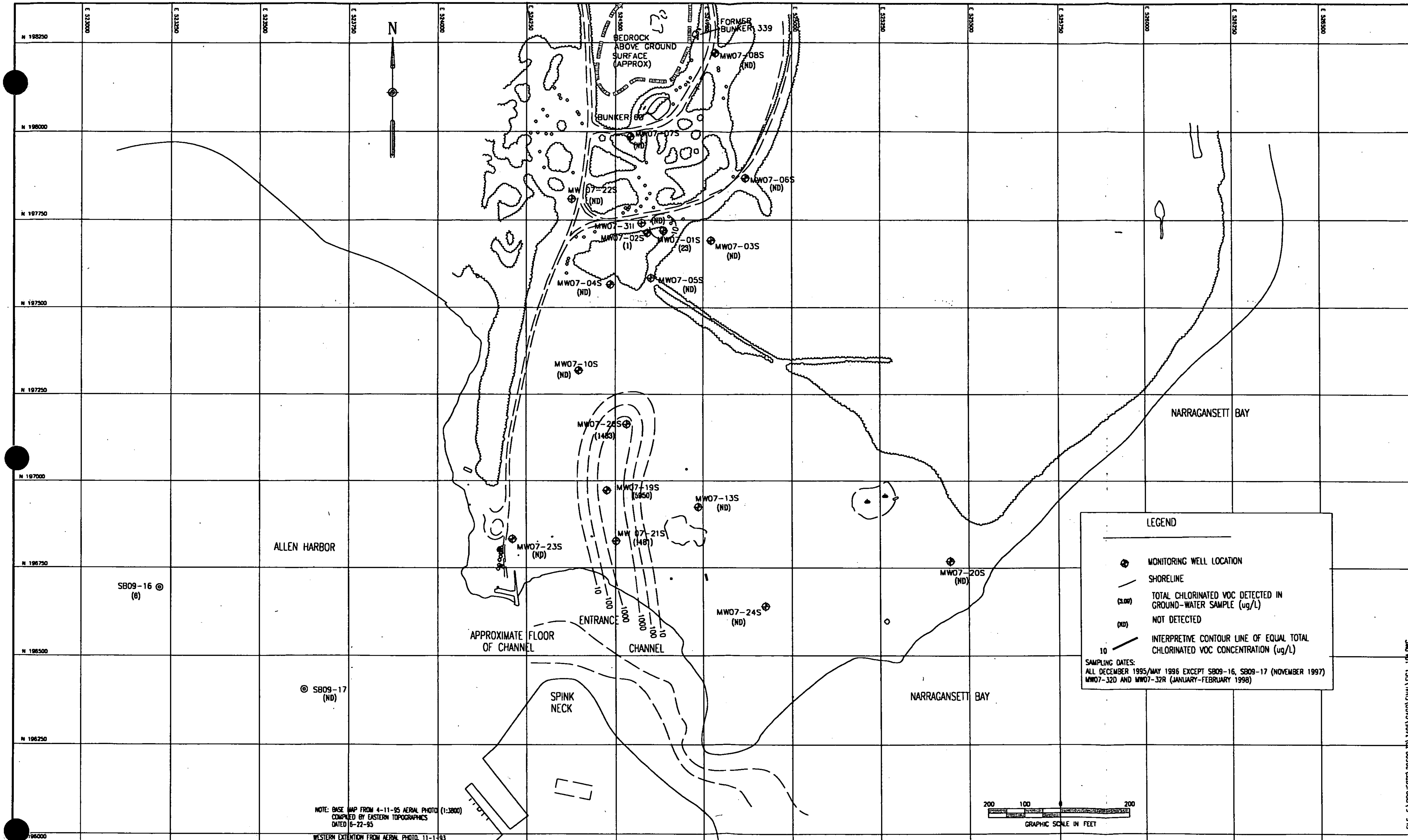
PROJECT NUMBER 29600.32
SCALE AS SHOWN
FILE NAME FIG1-18A
LAYER NAME 12-1-ROCK-LOW
FIGURE NUMBER 1-18

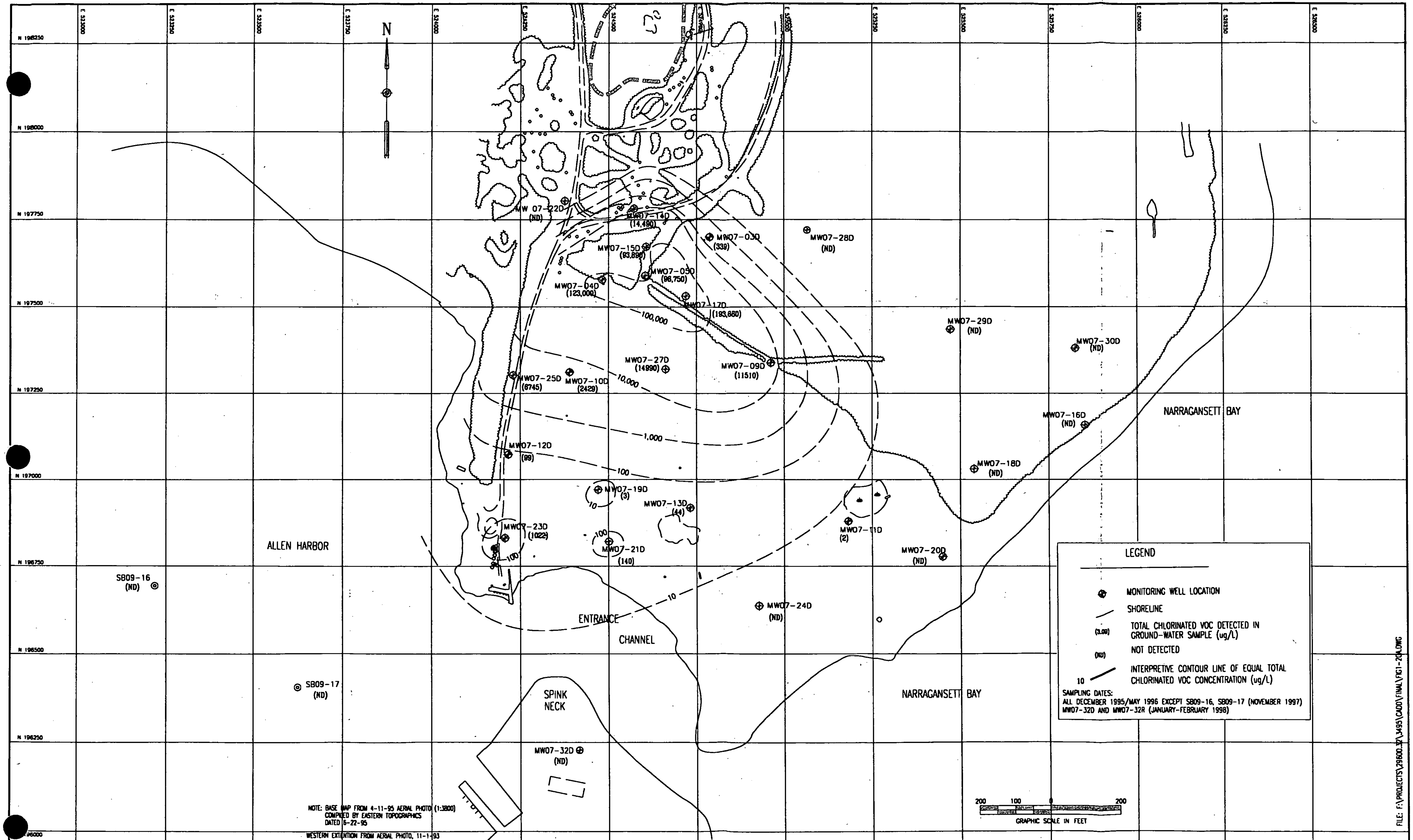


EA ENGINEERING, SCIENCE, AND TECHNOLOGY

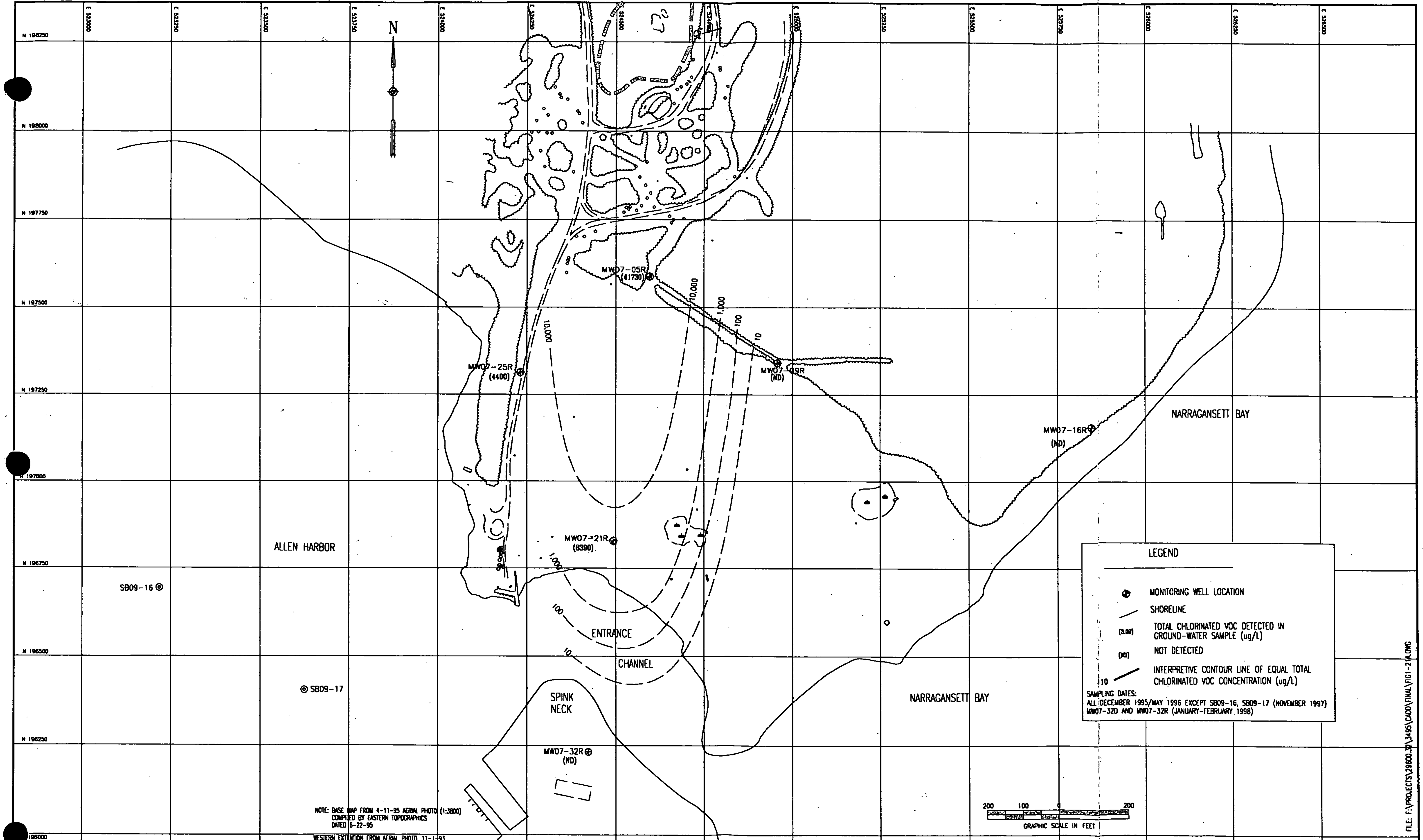
DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
JAS	RWC	4-23-98	29600.32	FIG1-19A
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	FIGURE
JAS	JAS	AS SHOWN	FIG1-19A	1-19

NORTHERN DIVISION
CALF PASTURE POINT, IR PROGRAM SITE 07
NCBC DAVISVILLE, RHODE ISLAND

TOTAL CHLORINATED VOC DETECTED IN GROUND-WATER SAMPLES, SHALLOW WELLS
FIGURE 1-19



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	DESIGNED BY JAS	DRAWN BY RWC	DATE 4-23-98	PROJECT NO. 29600.32	FILE NAME FIG1-20A	NORTHERN DIVISION CALF PASTURE POINT, IR PROGRAM SITE 07 NCBC DAVISVILLE, RHODE ISLAND	TOTAL CHLORINATED VOC DETECTED IN GROUND-WATER SAMPLES, DEEP WELLS FIGURE 1-20
	CHECKED BY JAS	PROJECT MGR. JAS	SCALE AS SHOWN	DRAWING NO. -	FIGURE 1-20		

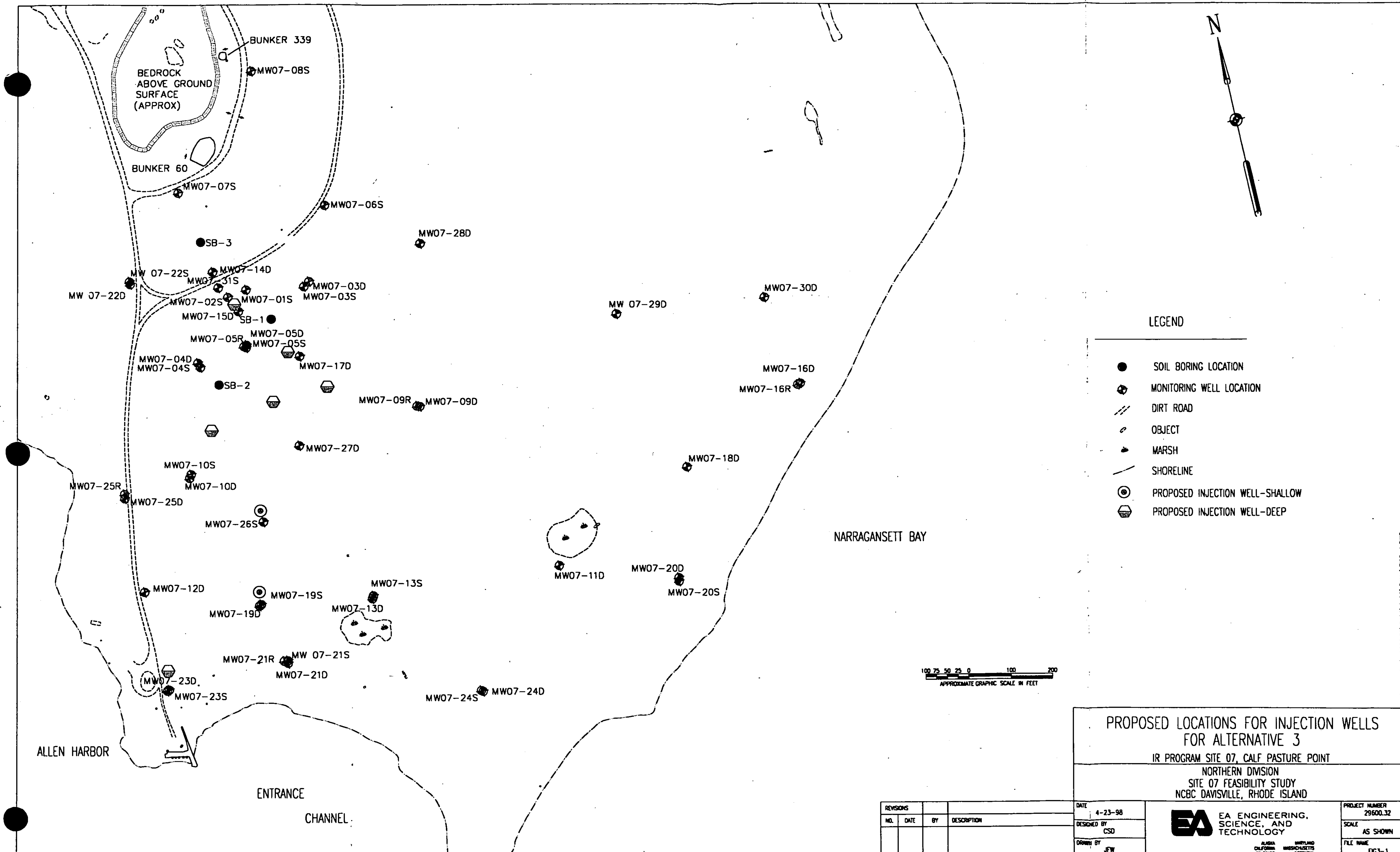


EA ENGINEERING, SCIENCE, AND TECHNOLOGY

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
JAS	RWC	4-23-98	29600.32	FIG1-21A
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	FIGURE
JAS	JAS	AS SHOWN	-	1-21

NORTHERN DIVISION
CALF PASTURE POINT, IR PROGRAM SITE 07
NCBC DAVISVILLE, RHODE ISLAND

TOTAL CHLORINATED VOC DETECTED IN
IN GROUND-WATER SAMPLES, BEDROCK WELLS
FIGURE 1-21



NOTE: BASE MAP FROM 4-11-95 AERIAL PHOTO (1:3800)
COMPILED BY EASTERN TOPOGRAPHICS
DATED 6-22-95

PROPOSED LOCATIONS FOR INJECTION WELLS FOR ALTERNATIVE 3

IR PROGRAM SITE 07, CALF PASTURE POINT

NORTHERN DIVISION
SITE 07 FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

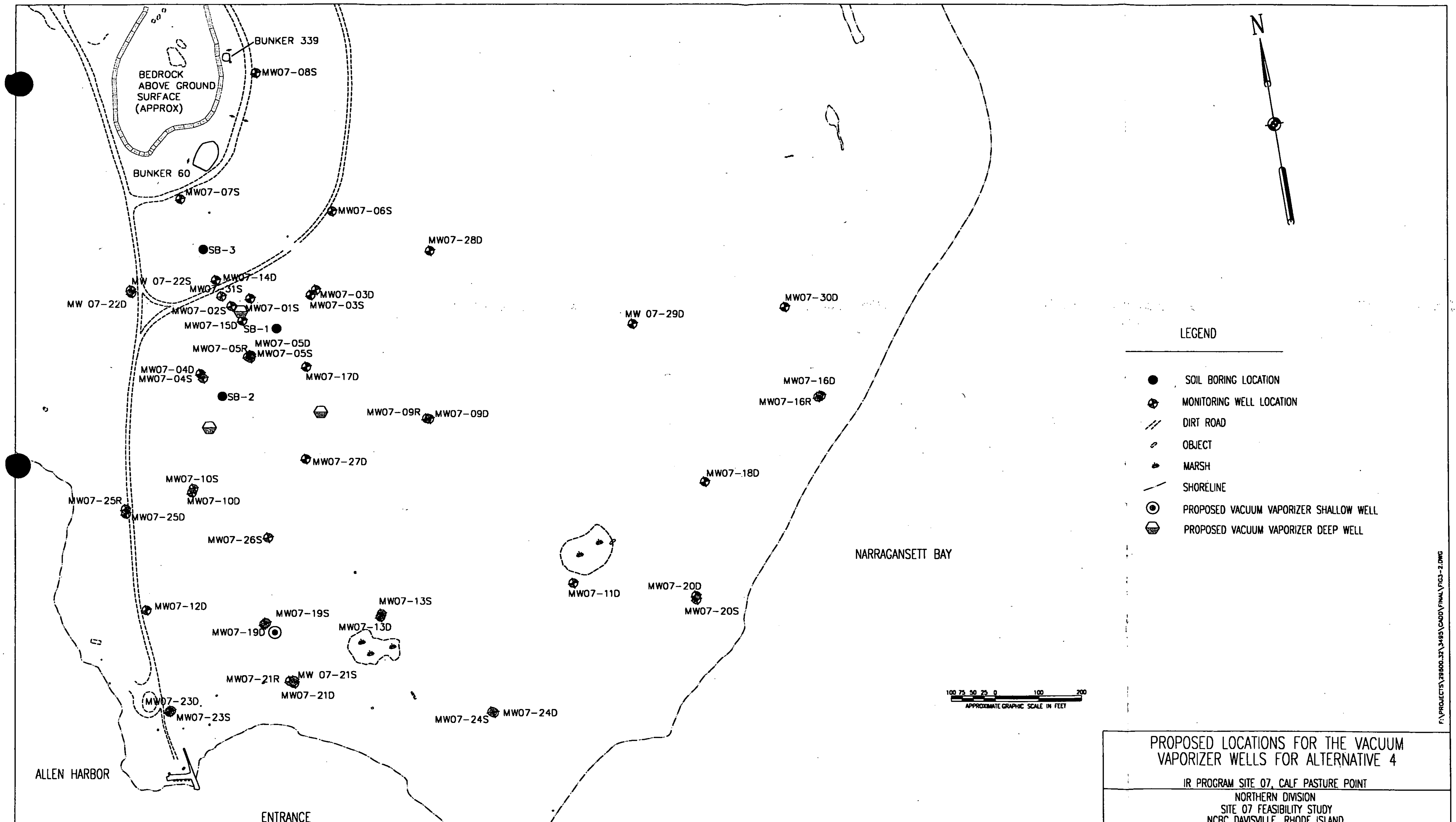
REVISIONS			
NO.	DATE	BY	DESCRIPTION

DATE 4-23-98
DESIGNED BY CSD
DRAWN BY JFW
CHECKED BY JDR
PROJECT MANAGER JAS

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
175 MIDDLESEX TURNPIKE
BEDFORD, MA 01730
781.275.8846

ALASKA, CALIFORNIA, COLORADO, DELAWARE, FLORIDA, GEORGIA, HAWAII, ILLINOIS, MARYLAND, MASSACHUSETTS, NEBRASKA, NEW JERSEY, NEW YORK, NORTH CAROLINA, TEXAS, WASHINGTON

PROJECT NUMBER 29600.32
SCALE AS SHOWN
FILE NAME FIG3-1
LAYER NAME
FIGURE NUMBER 3-1



NOTE: BASE MAP FROM 4-11-95 AERIAL PHOTO (1:3800)
COMPILED BY EASTERN TOPOGRAPHICS
DATED 6-22-95

PROPOSED LOCATIONS FOR THE VACUUM VAPORIZER WELLS FOR ALTERNATIVE 4

IR PROGRAM SITE 07, CALF PASTURE POINT

NORTHERN DIVISION
SITE 07 FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

REVISIONS			
NO.	DATE	BY	DESCRIPTION

DATE 4-23-98
DESIGNED BY CSD
DRAWN BY JFW
CHECKED BY JDR
PROJECT MANAGER JAS

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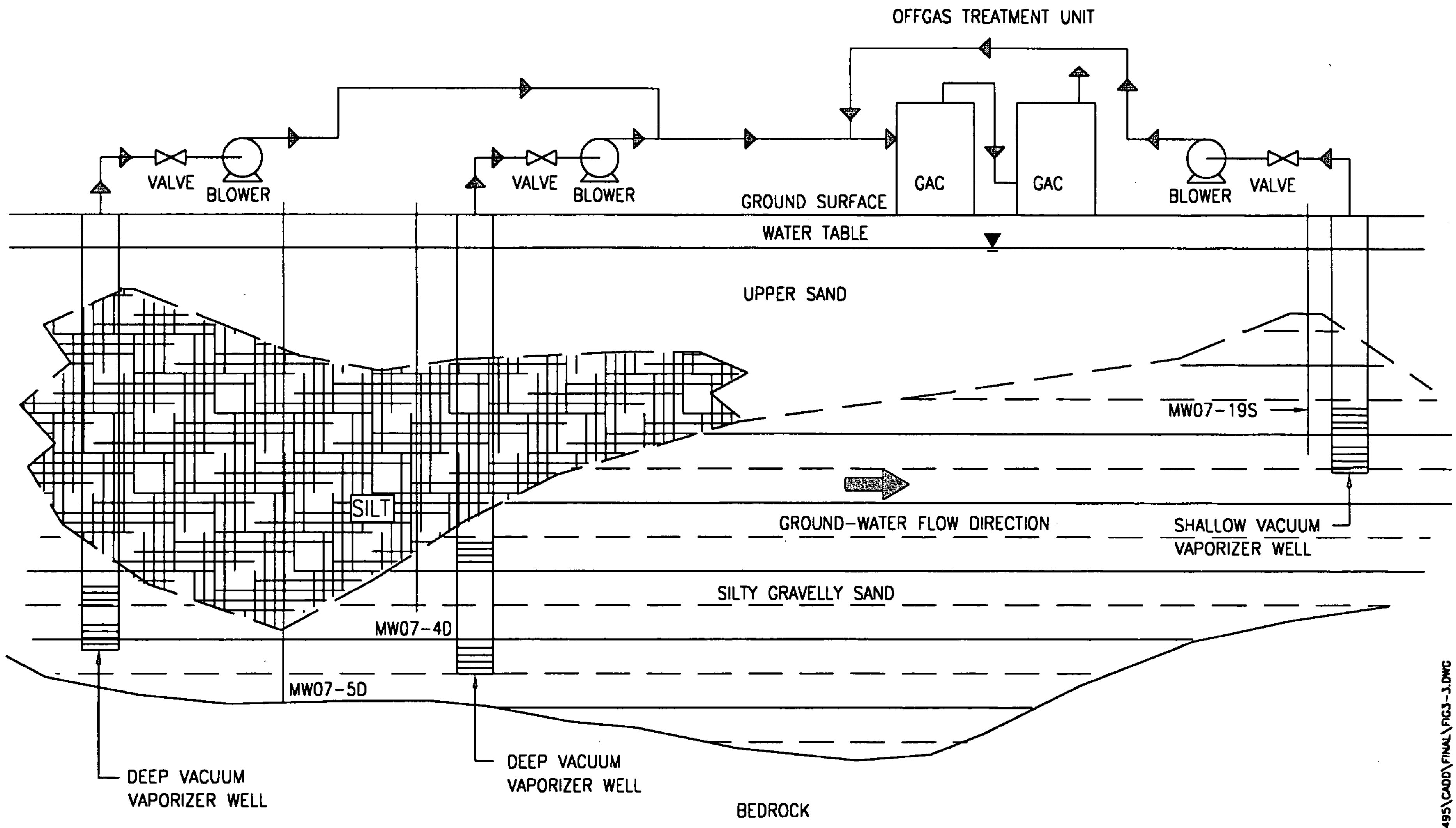
BEDFORD, MA 01730
781.275.8846

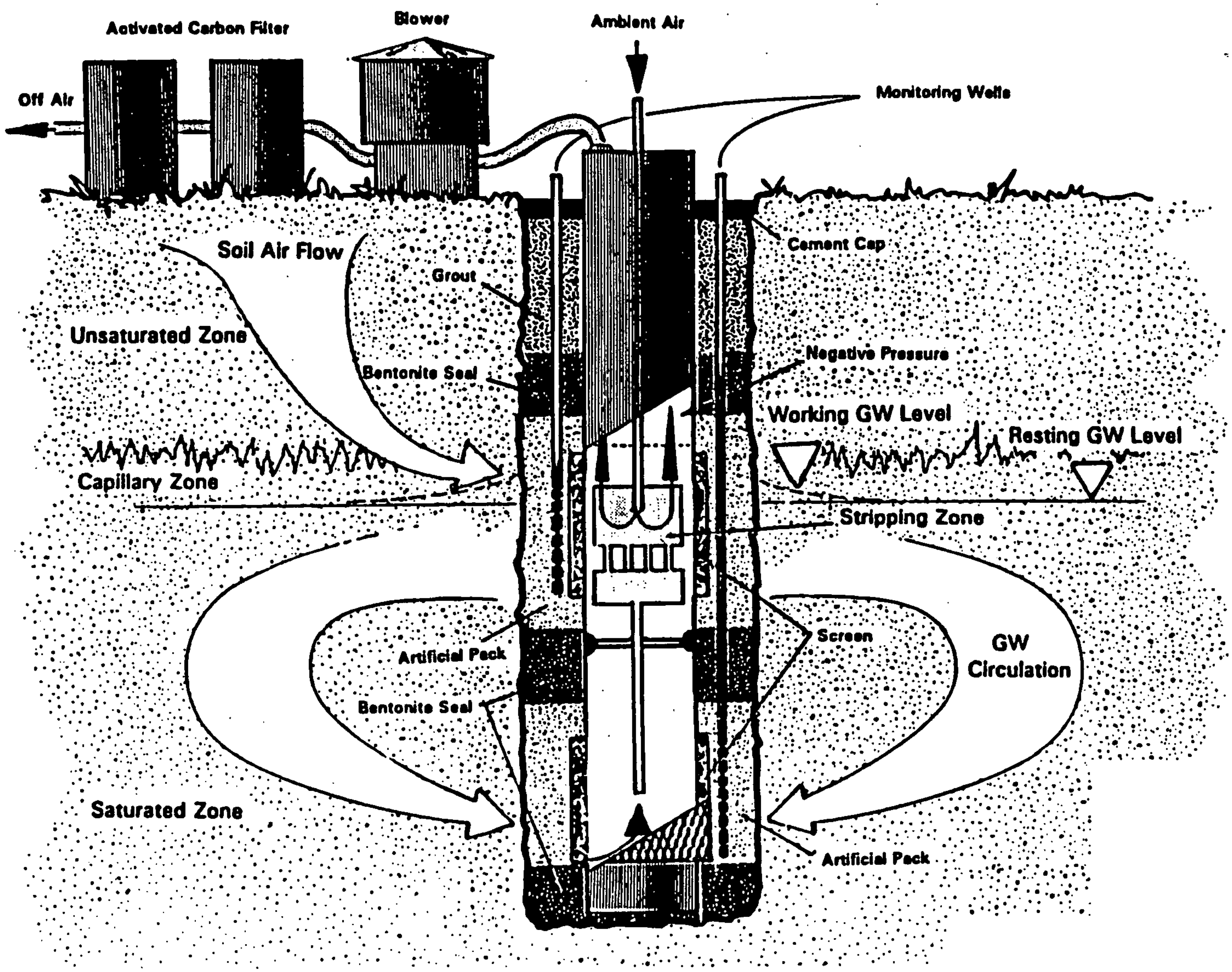
PROJECT NUMBER 29600.32
SCALE AS SHOWN
FILE NAME FIG3-2
LAYER NAME
FIGURE NUMBER 3-2

F:\PROJECTS\29600.32\3493\CADD\FINAL\FIG3-2.DWG



FILE:PROJECTS\29600.32\3495\CADD\FINAL\FIG3-3.DWG

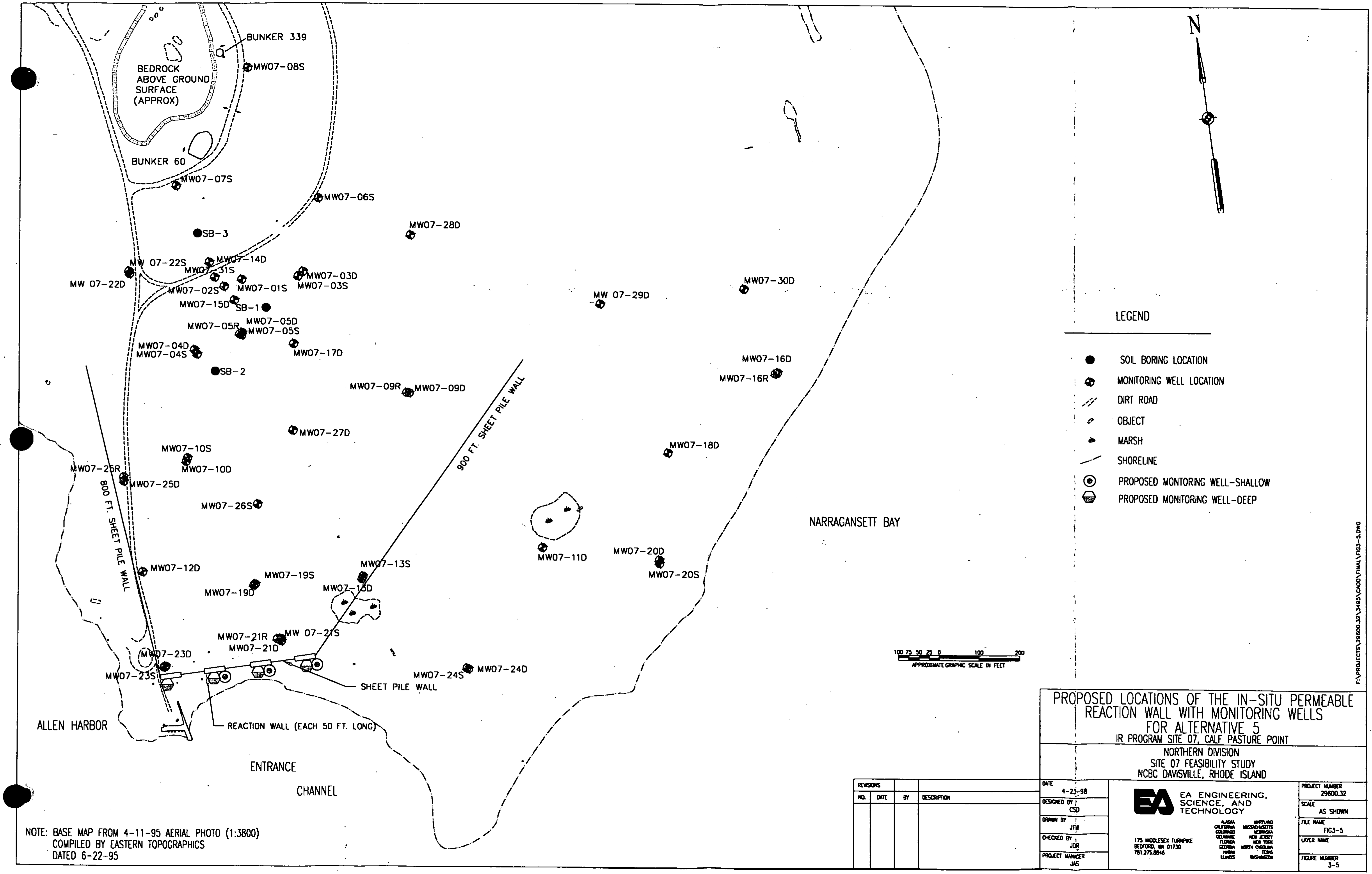
EA ENGINEERING, SCIENCE, AND TECHNOLOGY	NORTHERN DIVISION SITE 07 FEASIBILITY STUDY NCBC DAVISVILLE, RHODE ISLAND	CONCEPTUAL DIAGRAM FOR ALTERNATIVE 4 VACUUM VAPORIZER WELL SYSTEM	DESIGNED BY CSD	DRAWN BY JFW	DATE AUGUST 1997	PROJECT NO. 29600.32
			CHECKED BY JR	PROJECT MGR. JAS	SCALE NTS	FIGURE 3-3

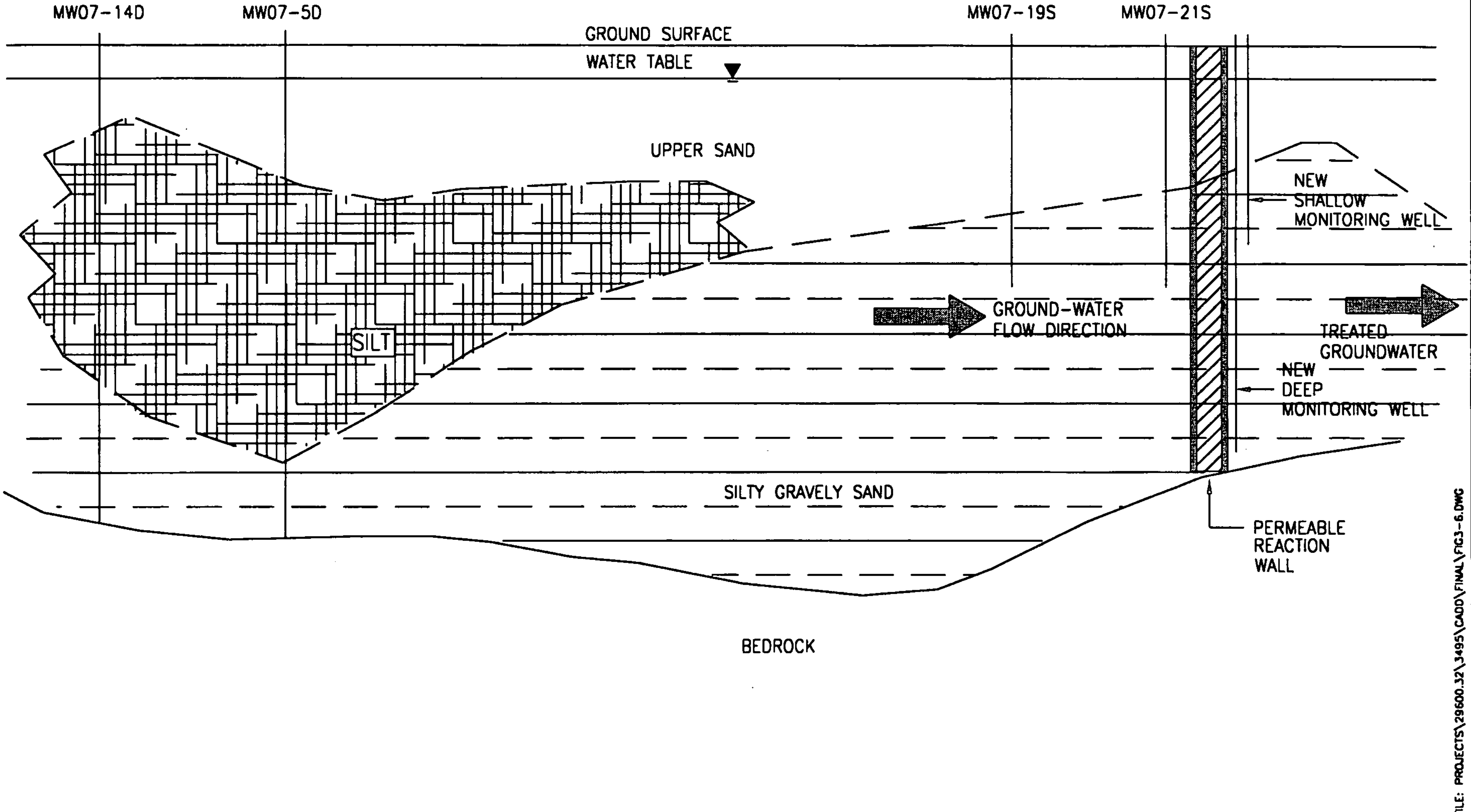


SOURCE: SITE Technology Profile

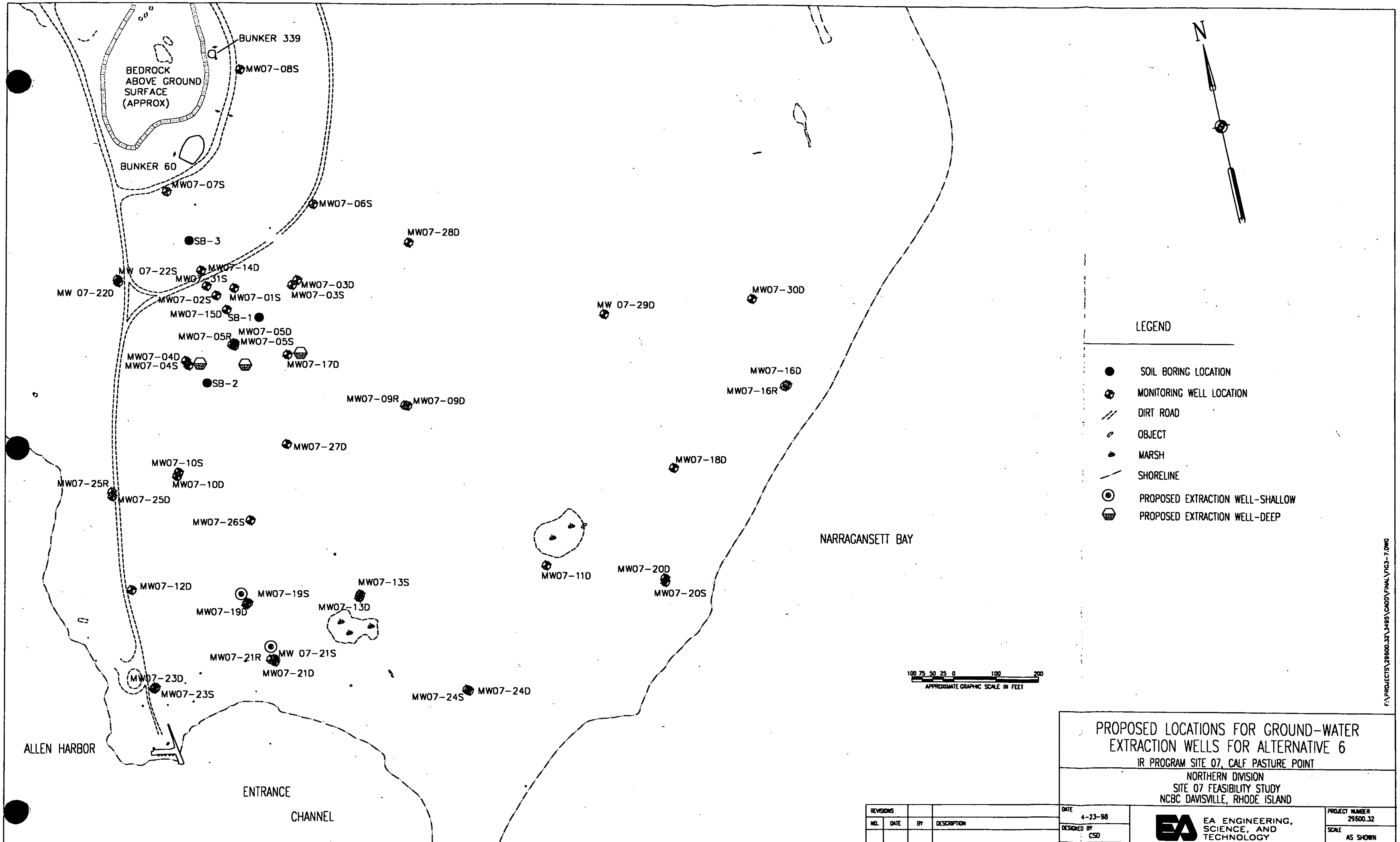
FILE: F:\PROJECTS\29600.32\3495\CADD\FINAL\FIG3-4.DWG

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	NORTHERN DIVISION SITE 07 FEASIBILITY STUDY NCBC DAVISVILLE, RHODE ISLAND	CONCEPTUAL DIAGRAM FOR TYPICAL VACUUM VAPORIZER WELL SPECIFICATIONS	DESIGNED BY CSD	DRAWN BY JFW	DATE 7-17-97	PROJECT NO. 29600.32
			CHECKED BY JR	PROJECT MGR. JAS	SCALE -	FIGURE FIG 3-4


N
BUNKER 339
BEDROCK ABOVE GROUND SURFACE (APPROX)
BUNKER 60
MW07-08S
MW07-07S
MW07-06S
MW07-28D
SB-3
MW 07-22S
MW07-14D
MW07-31S
MW 07-22D
MW07-02S
MW07-01S
MW07-03D
MW07-03S
MW07-15D
SB-1
MW07-05R
MW07-05D
MW07-05S
MW07-04D
MW07-04S
MW07-17D
SB-2
MW 07-29D
MW07-30D
MW07-16D
MW07-16R
MW07-09R
MW07-09D
MW07-27D
900 FT. SHEET PILE WALL
MW07-10S
MW07-10D
MW07-25R
MW07-25D
800 FT. SHEET PILE WALL
MW07-26S
MW07-18D
MW07-11D
MW07-20D
MW07-20S
NARRAGANSETT BAY
MW07-12D
MW07-13S
MW07-19S
MW07-19D
MW07-13D
MW07-21R
MW 07-21S
MW07-21D
MW07-23D
MW07-23S
MW07-24S
MW07-24D
SHEET PILE WALL
REACTION WALL (EACH 50 FT. LONG)
ALLEN HARBOR
ENTRANCE
CHANNEL
NOTE: BASE MAP FROM 4-11-95 AERIAL PHOTO (1:3800)
COMPILED BY EASTERN TOPOGRAPHICS
DATED 6-22-95
LEGEND
SOIL BORING LOCATION
MONITORING WELL LOCATION
DIRT ROAD
OBJECT
MARSH
SHORELINE
PROPOSED MONTORING WELL-SHALLOW
PROPOSED MONITORING WELL-DEEP
100 75 50 25 0 100 200
APPROXIMATE GRAPHIC SCALE IN FEET
F:\PROJECTS\29600.32\3495\CADD\FINAL\FIG3-5.DWG
PROPOSED LOCATIONS OF THE IN-SITU PERMEABLE REACTION WALL WITH MONITORING WELLS FOR ALTERNATIVE 5
IR PROGRAM SITE 07, CALF PASTURE POINT
NORTHERN DIVISION
SITE 07 FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND
REVISIONS
NO. DATE BY DESCRIPTION
DATE 4-23-98
DESIGNED BY CSD
DRAWN BY JFW
CHECKED BY JDR
PROJECT MANAGER JAS
EA ENGINEERING, SCIENCE, AND TECHNOLOGY
175 MIDDLESEX TURNPIKE
BEDFORD, MA 01730
781.275.8846
PROJECT NUMBER 29600.32
SCALE AS SHOWN
FILE NAME FIG3-5
LAYER NAME
FIGURE NUMBER 3-5



EA ENGINEERING, SCIENCE, AND TECHNOLOGY	NORTHERN DIVISION SITE 07 FEASIBILITY STUDY NCBC DAVISVILLE, RHODE ISLAND	CONCEPTUAL DIAGRAM FOR ALTERNATIVE 5- IN-SITU PERMEABLE REACTION WALL	DESIGNED BY CSD	DRAWN BY JFW	DATE AUGUST 1997	PROJECT NO. 29600.32
			CHECKED BY JR	PROJECT MGR. JAS	SCALE NTS	FIGURE 3-6



NOTE: BASE MAP FROM 4-11-95 AERIAL PHOTO (1:3800)
COMPILED BY EASTERN TOPOGRAPHICS
DATED 6-22-95

PROPOSED LOCATIONS FOR GROUND-WATER EXTRACTION WELLS FOR ALTERNATIVE 6

IR PROGRAM SITE 07, CALF PASTURE POINT

NORTHERN DIVISION
SITE 07 FEASIBILITY STUDY
NCBC DAVISVILLE, RHODE ISLAND

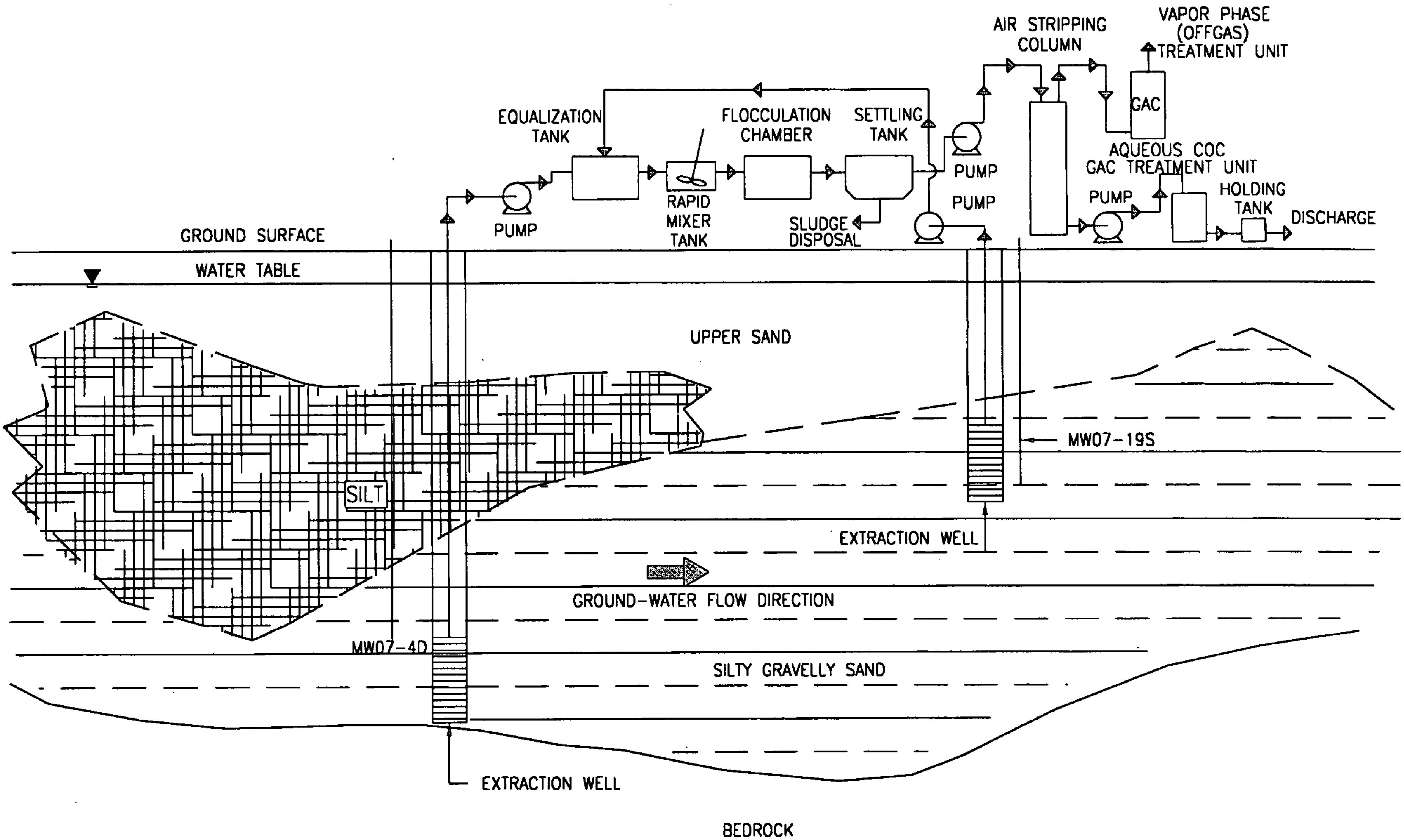
REVISIONS			
NO.	DATE	BY	DESCRIPTION

DATE 4-23-98
DESIGNED BY CSD
DRAWN BY JFW
CHECKED BY JDR
PROJECT MANAGER JAS

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
175 MIDDLESEX TURNPIKE
BEDFORD, MA 01730
781.275.8846

ALASKA MARYLAND
CALIFORNIA MASSACHUSETTS
COLORADO NEBRASKA
DELAWARE NEW JERSEY
FLORIDA NEW YORK
GEORGIA NORTH CAROLINA
HAWAII TEXAS
ILLINOIS WASHINGTON

PROJECT NUMBER 29600.32
SCALE AS SHOWN
FILE NAME FIG3-7
LAYER NAME
FIGURE NUMBER 3-7



FILE: PROJECTS\29600.32\3495\CADD\FINAL\FIG3-8.DWG

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	NORTHERN DIVISION SITE 07 FEASIBILITY STUDY NCBC DAVISVILLE, RHODE ISLAND	CONCEPTUAL DIAGRAM FOR ALTERNATIVE 6- GROUND-WATER EXTRACTION AND ONSITE AIR STRIPPING	DESIGNED BY CSD	DRAWN BY JFW	DATE AUGUST 1997	PROJECT NO. 29600.32
			CHECKED BY JR	PROJECT MGR. JAS	SCALE NTS	FIGURE 3-8

TABLE 2-1 SUMMARY OF MAXIMUM CONCENTRATIONS OF DETECTED ANALYTES IN SURFACE SOIL (0 TO 2 FT)

Chemical	Freq. of Detect.	Max. Conc. (a) (mg/kg)	Risk-Based Conc. (mg/kg)	PRG		
				EPA Guidance (mg/kg)	RIDEM Exposure (b) (mg/kg)	RIDEM Leachability (c) (mg/kg)
INORGANICS						
Aluminum	16 / 16	2,880	100,000	--	--	--
Arsenic	16 / 16	**1.5**	3.3	--	1.2	--
Barium	16 / 16	9.4	14,000	--	5,500	--
Beryllium	14 / 16	0.36	1.3	--	0.4	--
Cadmium	2 / 16	4.7	100	--	39	--
Calcium	16 / 16	5,790	--	--	--	--
Chromium	15 / 16	5.7	1,000 [d]	--	390 [g]	--
Cobalt	16 / 16	4.10	12,000	--	--	--
Copper	14 / 16	9.10	7,600	--	3,100	--
Cyanide	1 / 16	0.16	4,100	--	200	--
Iron	16 / 16	8,840	--	--	--	--
Lead	16 / 16	8.6	--	400	150 [h]	--
Magnesium	16 / 16	1,190	--	--	--	--
Manganese	16 / 16	116	10,000 [e]	--	390	--
Nickel	13 / 16	243	4,100	--	1,000	--
Potassium	15 / 16	448	--	--	--	--
Selenium	9 / 16	0.32	1,000	--	390	--
Sodium	4 / 16	411	--	--	--	--
Thallium	3 / 16	0.87	16 [f]	--	5.5	--
Vanadium	16 / 16	7.6	1,400	--	550	--
Zinc	15 / 16	32.1	61,000	--	6,000	--
SEMI-VOLATILES						
Bis(2-ethylhexyl)phthalate	1 / 4	0.38	410	--	46	--
VOLATILES						
Acetone	2 / 19	0.037	20,000	--	7,800	--
Chloroform	1 / 19	0.001	940	--	1.2	--
Toluene	1 / 19	0.003	110	--	190	32
1,1,1-Trichloroethane	2 / 19	0.006	18,000	--	540	11

TABLE 2-1 SUMMARY OF MAXIMUM CONCENTRATIONS OF DETECTED ANALYTES IN SURFACE SOIL (0 TO 2 FT) (Continued)

Chemical	Freq. of Detect.	Max. Conc. (a) (mg/kg)	Risk-Based Conc. (mg/kg)	PRG		
				EPA Guidance (mg/kg)	RIDEM Exposure (b) (mg/kg)	RIDEM Leachability (c) (mg/kg)
PESTICIDES / PCB						
4,4'-DDE	1 / 12	0.019	17	--	--	--
4,4'-DDT	1 / 12	0.022	17	--	--	--

Notes:

-- Not available
Data shown in **boldface print** indicate results that exceeded PRG.
Risk Based Concentrations (RBC) based on EPA Region III guidance (EPA/903/R-93-001).
(a) Data summarized from the Phase I, II, and III RI reports.
(b) Method 1 Residential Direct Soil Exposure Criteria
(c) Method 1 Class GB Leachability Criteria
(d) RBC for hexavalent chromium, the most toxic form of chromium.
(e) RBC for manganese recalculated using the updated RfD for non-dietary exposures of 0.05 mg/kg-day from IRIS (1996).
(f) RBC for thallium carbonate, the lowest available RBC for a thallium compound.
(g) Criterion for Chromium VI (most conservative)
(h) Since RIDEM's Remediation Regulations do not contain a Method 1 soil objective for lead, this PRG is based on the Rhode Island Department of Health's (RIDoH) Rules and Regulations for Lead Poisoning Prevention where 150 mg/kg is considered "lead free"; 150 to 500 mg/kg is considered "lead safe" (permissible) in surface soil.

TABLE 2-2 SUMMARY OF MAXIMUM CONCENTRATIONS OF DETECTED ANALYTES IN SOIL (0 TO 10 FT)

Chemical	Frequency of Detection	Maximum Concentration (a) (mg/kg)	Risk-Based Concentration (mg/kg)	PRG	
				RIDEM Direct Exposure (b) (mg/kg)	RIDEM Leachability (c) (mg/kg)
SEMIVOLATILES					
Bis(2-ethylhexyl)phthalate	2 / 8	0.38	410	410	--
VOLATILES					
Acetone	8 / 37	6.1	20,000	10,000	--
Chloroform	1 / 37	0.001	940	940	--
1,1,2,2-Tetrachloroethane	1 / 37	0.015	29	29	--
Toluene	2 / 37	0.003	41,000	10,000	54
1,1,1-Trichloroethane	4 / 37	0.006	18,000	10,000	160
Trichloroethene	1 / 37	0.018	520	520	20
PESTICIDES / PCB					
4,4'-DDE	1 / 14	0.019	17	--	--
4,4'-DDT	1 / 14	0.022	17	--	--

Notes:

-- Not Available
(a) Data summarized from the Phase I, II, and III RI reports.
(b) Method 1 Commercial/Industrial criteria
(c) Method 1 Class GB Leachability Criteria

TABLE 2-3 COMPARISON OF MAXIMUM CONCENTRATION OF INORGANICS IN SOIL WITH NCBC BACKGROUND CONCENTRATIONS

Inorganic Chemical	Frequency of Detection	Maximum Concentrations at Site 07 (a,b) (mg/kg)	Range of Concentrations at NCBC Davisville Background Locations (c) (mg/kg)
Aluminum	26 / 26	7,720	1,170 - 8,560
Antimony	1 / 26	**3.9**	ND
Arsenic	26 / 26	2.2	0.59 - 8.1
Barium	26 / 26	**18.6**	5.6 - 15.5
Beryllium	22 / 26	0.49	ND - 0.66
Cadmium	2 / 26	**4.7***	ND - 0.46
Calcium	26 / 26	**8,390**	62.7 - 627
Chromium	25 / 26	**13.1**	3.5 - 9.6
Cobalt	26 / 26	**6.1**	ND - 4.6
Copper	22 / 26	14.6	3.9 - 15
Cyanide	1 / 26	**0.16***	ND
Iron	26 / 26	**15,600**	3,810 - 12,000
Lead	26 / 26	8.6*	3.4 - 53.8
Magnesium	26 / 26	**3,250**	325 - 1,220
Manganese	26 / 26	137	21.8 - 150
Mercury	0 / 4	ND	ND - 0.03
Nickel	17 / 26	**243***	ND - 5
Potassium	23 / 26	**1,230**	145 - 728
Selenium	12 / 26	0.32*	ND - 0.77
Silver	0 / 4	ND	ND - 0.06
Sodium	7 / 26	**411***	ND - 119
Thallium	3 / 26	**0.87***	ND
Vanadium	26 / 26	14.3	3.3 - 24.6
Zinc	24 / 26	33.6	10.3 - 172

Notes:

NA Not Available ND Non-Detect

Data shown in **boldface print** indicate results that exceeded NCBC Davisville background concentrations for surface soil (footnote c)

* = data reported from surface soil sample

(a) Data summarized from the Phase I, II, and III RI reports.

(b) Includes data from surface and subsurface soil samples from Phase I, II, and III RI reports.

(c) Based on surface soil samples collected from non-impacted areas at or near Sites 02, 03, 05, 06, and 07 (data provided in TRC 1994).

TABLE 2-4 COMPARISON OF MAXIMUM GROUND-WATER CONCENTRATIONS (a) TO PRG

Constituent	Frequency of Detection	Max. Conc. in Shallow GW (μg/L)	Frequency of Detection	Max. Conc. in Deep GW (μg/L)	Frequency of Detection	Max. Conc. in Bedrock GW (μg/L)	PRG	Potential Treatment Goals (g)	
							RIDEM Method 1 GB Criteria (μg/L)	CWA AWQC (e) (μg/L)	SDWA MCL/SMCL (μg/L)
INORGANICS									
Aluminum	5/20	110	7/22	129,000		ND	--	--	--/50 to 200
Antimony		27.1		ND		ND	--	146	6
Arsenic	11/20	46.9	6/25	63.5	1/5	4.2	--	0.0022	50
Barium	12/22	51.8	22/30	253	4/5	123	--	1,000	2,000
Beryllium	1/20	3.5	3/20	6.4		ND	--	0.0037	4
Cadmium		ND		ND		ND	--	10	5
Calcium	25/25	270,000	31/31	270,000	5/5	275,000	--	--	--
Chromium	1/14	4.2	3/12	292		ND	--	(c)	100 (total)
Cobalt		ND	14/27	117	4/5	151	--	--	--
Copper	6/25	12.1	6/29	268		ND	--	--	--/1,000
Iron	20/24	53,100	27/31	295,000	5/5	15,500	--	300	--/300
Lead	5/5	21.4	7/7	125		ND	--	50	15 (d)
Magnesium	19/25	764,000	25/30	765,000	5/5	753,000	--	--	--
Manganese	22/25	3,830	31/31	4,100	5/5	15,500	--	50	--/50
Mercury		ND	2/26	0.15		ND	--	0.144	2
Nickel	2/14	19	5/13	320		ND	--	13.4	100
Potassium	24/25	239,000	31/31	262,000	5/5	203,000	--	--	--
Selenium	4/9	5.3	2/4	5.2		ND	--	10	50
Sodium	25/25	7,620,000	31/31	8,240,000	5/5	7,730,000	--	--	--
Thallium	7/14	29.3	13/16	31.6	3/4	29	--	13	2
Vanadium		ND	3/20	224		ND	--	--	--
Zinc	1/25	75	5/30	626	1/5	56.9	--	--	--/5,000

TABLE 2-4 COMPARISON OF MAXIMUM GROUND-WATER CONCENTRATIONS [(a)] TO PRG (Continued)

Constituent	Frequency of Detection	Max. Conc. in Shallow GW (μg/L)	Frequency of Detection	Max. Conc. in Deep GW (μg/L)	Frequency of Detection	Max. Conc. in Bedrock GW (μg/L)	PRG	Potential Treatment Goals (g)	
							RIDEM Method 1 GB Criteria (μg/L)	CWA AWQC (e) (μg/L)	SDWA MCL/SMCL (μg/L)
SEMI-VOLATILES									
Styrene		ND	1/26	72		ND	2,200	--	100
VOLATILES									
Acetone	4/21	1,800	3/21	190		ND	--	--	--
Benzene		ND	2/27	**550**		ND	140	0.66	5
Bromodichloromethane		ND	1/26	78		ND	--	--	100 (b)
2-Butanone	1/23	5	1/22	34		ND	--	--	--
Carbon Disulfide		ND	2/26	4	1/5	2	--	--	--
Chlorobenzene		ND	1/26	100		ND	3,200	488	--
Chloroform		ND	3/26	240	1/5	48	--	0.19	100 (b)
Chloromethane		ND	1/26	98		ND	--	--	--
1,1-Dichloroethane		ND	1/26	74		ND	--	--	--
1,2-Dichloroethane	1/25	30	2/26	**120**	1/5	1	110	0.94	5
1,1-Dichloroethene		ND	1/25	**16**	1/5	**21**	7	0.033	7
1,2-Dichloroethene (total)	5/25	1,400	19/30	**5,700**	3/5	2,200	cis 2,400 trans 2,800	--	cis 70 trans 100
1,2-Dichloropropane		ND	1/25	98		ND	3,000	--	5
1,3-Dichloropropene		ND	1/25	66		ND	--	--	--
1,1,2,2 Tetrachloroethane	5/24	1,500	18/30	77,000	3/5	12,000	--	0.17	--
Tetrachloroethene	2/25	1	4/26	**1,000**	1/5	51	150	0.8	5
Toluene		ND	1/26	96		ND	1,700	14,300	1,000
1,1,2-Trichloroethane	3/25	130	13/30	1,200	1/5	390	--	0.6	5
Trichlorethene	6/25	**3,400**	19/29	**120,000**	3/5	**27,000**	540	2.7	5
Vinyl chloride	1/25	23	3/26	31	1/5	17	--	2	2

TABLE 2-4 COMPARISON OF MAXIMUM GROUND-WATER CONCENTRATIONS [(a)] TO PRG (Continued)

Constituent	Frequency of Detection	Max. Conc. in Shallow GW (µg/L)	Frequency of Detection	Max. Conc. in Deep GW (µg/L)	Frequency of Detection	Max. Conc. in Bedrock GW (µg/L)	PRG	Potential Treatment Goals (g)	
							RIDEM Method 1 GB Criteria (µg/L)	CWA AWQC (e) (µg/L)	SDWA MCL/SMCL (µg/L)
Xylenes (total)		ND	1/26	220		ND	--	--	10,000

Notes:

-- Not Available ND = Non-Detect

Data shown in **boldface print** indicate results that exceeded RIDEM Method 1 GB Criteria.

(a) Data summarized from the Phase I, II, and III RI reports.

(b) 100 ppb as Total Trihalomethanes (i.e., Chloroform + Bromodichloromethane + Chlorodibromomethane + Bromoform)

(c) 170,000 as CrIII and 50 as CrVI

(d) Action level at the tap.

(e) Protective of human health risk (10^{-6}) for carcinogens ("water and organisms" criteria)

TABLE 2-5 COMPARISON OF MAXIMUM GROUND-WATER INORGANIC CONCENTRATIONS [a] TO NCBC DAVISVILLE BACKGROUND LEVELS

Inorganic Constituent	Max. Conc. in Shallow GW (µg/L)	Max. Conc. in Deep GW (µg/L)	Max. Conc. in Bedrock GW (µg/L)	NCBC Davisville Background Concentrations (b) (µg/L)
Aluminum	110	**129,000**	ND	5,315
Antimony	**27.1**	ND	ND	6
Arsenic	**46.9**	**63.5**	4.2	6.4
Barium	51.8	**253**	**123**	80.5
Beryllium	**3.5**	**6.4**	ND	1.3
Cadmium	ND	ND	ND	3
Calcium	**270,000**	**270,000**	**275,000**	13,302
Chromium	4.2	**292**	ND	214
Cobalt	ND	**117**	**151**	24.9
Copper	12.1	**268**	ND	25.8
Iron	**53,100**	**295,000**	15,500	25,500
Lead	**21.4**	**125**	ND	4.8
Magnesium	**764,000**	**765,000**	**753,000**	5,126
Manganese	**3,830**	**4,100**	**15,500**	3,292
Mercury	ND	0.15	ND	ND (<0.2)
Nickel	19	**320**	ND	154
Potassium	**239,000**	**262,000**	**203,000**	3,843
Selenium	**5.3**	**5.2**	ND	2.2
Silver	ND	ND	ND	1
Sodium	**7,620,000**	**8,240,000**	**7,730,000**	12,346
Thallium	**29.3**	**31.6**	**29**	4.1
Vanadium	ND	**224**	ND	24.4
Zinc	75	**626**	56.9	89.9

Notes:

ND = Non-Detect

Data shown in **boldface print** indicate results that exceeded NCBC Davisville background levels.

(a) Data summarized from the Phase I, II, and III RI reports.

(b) Data from Basewide Ground-Water Inorganics Study Report (Stone & Webster, 1996).

TABLE 2-6 SUMMARY OF TARGET CONSTITUENT CONCENTRATIONS IN SHORELINE SEDIMENT

Chemical	Frequency of Detection	Maximum Concentration [a] (mg/kg)
INORGANICS		
Aluminum	3 / 3	14,400
Arsenic	8 / 8	22.1
Barium	3 / 3	125
Beryllium	1 / 3	0.4
Cadmium	3 / 8	3.9
Calcium	3 / 3	4,640
Chromium	8 / 8	40.2
Cobalt	3 / 3	83.3
Copper	7 / 8	50.4
Iron	3 / 3	70,200
Lead	8 / 8	91.3
Magnesium	3 / 3	4,690
Manganese	3 / 3	730
Nickel	8 / 8	121
Potassium	1 / 3	707
Silver	4 / 8	1.10
Sodium	3 / 3	270
Thallium	1 / 3	5.50
Vanadium	3 / 3	27.4
Zinc	8 / 8	591
SEMIVOLATILES		
Acenaphthene	5 / 8	0.00088
Acenaphthylene	5 / 8	0.00323
Anthracene	5 / 8	0.00876
Benzo(a)anthracene	5 / 8	0.0342
Benzo(a)pyrene	5 / 8	0.0342
Benzo(b)fluoranthene	6 / 8	0.0556
Benzo(e)pyrene	5 / 5	0.0282
Benzo(g,h,i)perylene	5 / 8	0.0208
Benzo(k)fluoranthene	6 / 8	0.054
Bis(2-ethylhexyl)phthalate	2 / 3	0.3
Chrysene	5 / 8	0.0386

TABLE 2-6 SUMMARY OF TARGET CONSTITUENT CONCENTRATIONS IN SHORELINE SEDIMENT (Continued)

Chemical	Frequency of Detection	Maximum Concentration [a] (mg/kg)
Dibenzo(a,h)anthracene	5 / 8	0.00559
Fluoranthene	6 / 8	0.0775
Fluorene	5 / 8	0.00243
Indeno(1,2,3-cd)pyrene	5 / 8	0.0219
4-Methylphenol	1 / 3	1.3
Naphthalene	5 / 8	0.00395
Phenanthrene	5 / 8	0.0289
Pyrene	6 / 8	0.0721
VOLATILES		
2-Butanone	1 / 3	0.16
PESTICIDES / PCB		
beta-BHC	1 / 3	0.0017
delta-BHC	1 / 3	0.00022
alpha Chlordane	1 / 3	0.0001
gamma Chlordane	1 / 3	0.00053
4,4'-DDD	2 / 3	0.003
4,4'-DDE	1 / 3	0.011
Endrin aldehyde	1 / 3	0.00078
Aroclor-1260	1 / 3	0.06

Notes:

-- not available

(a) Samples included AHW-10 through AHW-14 and SD-05 through SD-07.

TABLE 2-7 SUMMARY STATISTICS FOR CONSTITUENTS IN SHELLFISH

Chemical of Concern	Frequency Detected	Range of Detection (mg/kg)	Arithmetic Mean (mg/kg)
INORGANICS			
Arsenic	6 / 6	0.27 - 2.5	1.1
Cadmium	6 / 6	0.05 - 2.39	0.49
Chromium	5 / 6	0.02 - 0.704	0.22
Copper	6 / 6	1.69 - 126	26
Lead	4 / 6	0.07 - 0.875	0.38
Mercury	4 / 4	0.01 - 49.1	20
Zinc	6 / 6	9.26 - 4,730	820
SEMIVOLATILES			
Benzo(a)pyrene	5 / 6	3×10^{-4} - 0.00606	0.0017
Benzo(b)fluoranthene	6 / 6	0.00371 - 0.0359	0.011
Benzotriazole	4 / 4	0.00971 - 0.0254	0.021
Chlorinated benzotriazole	4 / 4	0.00223 - 0.00362	0.0027
Dibenzo(a,h)anthracene	5 / 6	1.3×10^{-4} - 0.00128	0.00064
PESTICIDES / PCB			
Aldrin	1 / 2	2.44×10^{-4} - $<2.74 \times 10^{-4}$	0.00019
4,4'-DDE	4 / 5	$<4 \times 10^{-5}$ - 0.0228	0.0064
Aroclor-1242	2 / 6	<0.00082 - 0.022007	0.0074
Aroclor-1254	6 / 6	0.027 - 0.133501	0.058
Aroclor-1260	2 / 2	0.0322 - 0.0849	0.059

NOTES:

< Indicates a non-detect at the given detection limit.

TABLE 2-8 REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS FOR EACH MEDIA/RECEPTOR OF CONCERN AT SITE 07

Media/Receptor	Remedial Action Objectives	General Response Actions
Surface Soil	• None identified.	• None identified.
Subsurface Soil	• None identified.	• None identified.
Shallow, Deep, and Bedrock Ground Water	• Prevent human exposure to COC in deep and bedrock ground water. • Ensure that the discharge of ground water to wetlands and offshore areas continues to pose no unacceptable risks from COC.	• Monitor site risks from COC. • Restrict potential use of site ground water. • Conduct active or passive remediation of shallow and deep ground water, as appropriate to reduce risks from COC concentrations.
Sediment	• None identified.	• None identified.
Wetlands	• None identified.	• None identified.
Shellfish	• None identified.	• None identified.

TABLE 2-9 WHOLE-SITE GENERAL RESPONSE ACTIONS AND ASSOCIATED REMEDIAL TECHNOLOGIES FOR SITE 07

General Response Actions	Remedial Technology Types and Process Options	Exposure Pathways or Remedial Goals Addressed by Technologies
No Action	None	None
Institutional Actions	Monitoring	To address the exposure pathway associated with hypothetical human contact with COC ground water.
	Point-of-Entry Treatment	
	Site Use Restrictions	
	Alternate Water Supply	
Ground-Water Containment Actions	Hydraulic Control • Extraction Wells • Injection Wells • Recovery Trench	To reduce the potential for offsite migration of COC via ground water or for use in conjunction with other remedial technologies.
	Vertical Barriers • Soil-Bentonite Slurry Wall • Sheet Pile Wall • Grout Curtain	
Ground-Water Treatment Actions	*In-Situ* Treatment • Bioremediation • Air Sparging/Vapor Extraction • Vacuum-Vaporizer Wells • Permeable Reaction Wall	To achieve ground-water PRG and reduce risks associated with ground water.
	Ex-Situ Treatment - Physical • Air Stripping • Filtration • Carbon Adsorption • Reverse Osmosis • UV Oxidation • Ultrafiltration	
	Ex-Situ Treatment - Biological • Aerobic Bioremediation • Anaerobic Bioremediation	

TABLE 2-9 WHOLE-SITE GENERAL RESPONSE ACTIONS AND ASSOCIATED REMEDIAL TECHNOLOGIES FOR SITE 07 (Continued)

General Response Actions	Remedial Technology Types and Process Options	Exposure Pathways or Remedial Goals Addressed by Technologies
	Ex-Situ Treatment - Chemical • Coagulation / Flocculation / Precipitation • Ion Exchange • Oxidation/Reduction • Incineration	
Ground-Water Discharge Actions	Discharge to POTW	Required as part of any remedial alternative involving ground-water extraction.
	Discharge to Surface Water	
	Reinjection/Recirculation	

TABLE 2-10 SUMMARY OF PRELIMINARY TEC OGY SCREENING FOR SITE 07, NCBC DAVISVILLE

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
NO ACTION	NONE	NOT APPLICABLE	NO ACTION	REQUIRED FOR CONSIDERATION
INSTITUTIONAL ACTIONS	MONITORING	NOT APPLICABLE	MONITORING OF COC IN ENVIRONMENTAL MEDIA	POTENTIALLY APPLICABLE
	POINT-OF-ENTRY TREATMENT	CARBON FILTERS	DOMESTIC WATER TREATMENT	NO RESIDENCES USE GROUND WATER AFFECTED BY SITE 07
		ION EXCHANGERS	DOMESTIC WATER TREATMENT	NO RESIDENCES USE GROUND WATER AFFECTED BY SITE 07
	SITE USE RESTRICTIONS	FENCING AND WARNING SIGNS	PERIMETER FENCING AND USE OF RESTRICTION WARNING SIGNS	WILL NOT ADDRESS SITE RISKS
		LAND USE RESTRICTIONS	DEED INCLUDES SITE DEVELOPMENT AND USE LIMITATIONS	POTENTIALLY APPLICABLE INCLUDES GROUND-WATER USE RESTRICTIONS
	ALTERNATE WATER SUPPLY	NEW WATER SOURCE	PROVISION OF POTABLE WATER SUPPLY	NO RESIDENCES USE GROUND WATER AFFECTED BY SITE 07
SOURCE CONTROL ACTIONS	CAPPING	VARIOUS	COVER OVER SOURCE AREA	NO UNACCEPTABLE RISK ASSOCIATED WITH SURFACE OR SUBSURFACE SOILS OR INFILTRATION
GROUND-WATER CONTAINMENT ACTIONS	HYDRAULIC CONTROL	EXTRACTION WELLS	HYDRAULIC GRADIENT REVERSAL THROUGH GROUND-WATER PUMPING	PLUME CONTAINMENT NOT FEASIBLE
		INJECTION WELLS	HYDRAULIC CONTROL BY REDIRECTING GROUND WATER	
		RECOVERY TRENCH	INTERCEPTOR TRENCH WITH EXTRACTION WELLS TO RECOVER AFFECTED GROUND WATER	
	VERTICAL BARRIERS	SLURRY WALL	PERIMETER TRENCH FILLED WITH SOIL-BENTONITE SLURRY	SALT AND SOLVENTS IN GROUND WATER MAY REDUCE EFFECTIVENESS
		SHEET PILE WALL	PERIMETER BARRIER WALL BUILT WITH INTERLOCKING Z-SECTION STEEL SHEET PILES	POTENTIALLY APPLICABLE
		GROUT CURTAIN	PREVENT HORIZONTAL MOVEMENT OF COC WITH PERIMETER BARRIER WALL	WILL NOT BE EFFECTIVE OR IMPLEMENTABLE

POTENTIAL OPTIONS

OPTIONS SCREENED OUT

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TABLE 2-10 (CONTINUED)

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
GROUND-WATER TREATMENT ACTIONS	IN-SITU TREATMENT	AEROBIC BIOREMEDIATION	INTRODUCTION OF NUTRIENTS AND OXYGEN INTO SUBSURFACE TO STIMULATE BIODEGREDATION	INEFFECTIVE FOR CHLORINATED COC
		ANAEROBIC BIOREMEDIATION	INTRODUCTION OF CARBON SOURCE INTO SUBSURFACE TO STIMULATE BIODEGREDATION	POTENTIALLY APPLICABLE
		AIR SPARGING	INJECTION OF AIR INTO AQUIFER TO REMOVE VOC USING VAPOR EXTRACTION	NOT EFFECTIVE DUE TO SILT LAYER
		VACUUM-VAPORIZER-WELLS	REMOVAL OF VOC FROM GROUND WATER USING SPECIALIZED VACUUM-VAPORIZER WELLS	POTENTIALLY APPLICABLE
		PERMEABLE REACTION WALL	INSTALLATION OF POROUS CHEMICAL/BIOLOGICAL REACTION WALL THROUGH WHICH GROUND WATER IS CHANNELED USING VERTICAL BARRIERS	POTENTIALLY APPLICABLE
	EX-SITU TREATMENT: PHYSICAL•	REVERSE OSMOSIS	REDUCTIONS OF CONCENTRATED DISSOLVED SOLIDS BY USE OF A SEMIPERMEABLE MEMBRANE UNDER HYDROSTATIC PRESSURE	INEFFECTIVE FOR SITE COC AND COST PROHIBITIVE FOR PRETREATMENT
		ULTRAFILTRATION	MEMBRANE FILTRATION PROCESS THAT SEPARATES COLLOIDS FROM SOLUTION OR SUSPENSION	INEFFECTIVE DUE TO LOW MOLECULAR WEIGHTS OF COC
		FILTRATION	FILTRATION OF SUSPENDED SOLIDS IS A STANDARD PRETREATMENT PROCESS	POTENTIALLY APPLICABLE AS PRETREATMENT TECHNOLOGY
		PRECIPITATION/ FLOCULATION/ SEDIMENTATION	PROCESS BY WHICH SOME OR ALL OF THE SUBSTANCE IN A SOLUTION IS TRANSFORMED INTO A SOLID PHASE	POTENTIALLY APPLICABLE AS PRETREATMENT TECHNOLOGY
		AIR STRIPPING	VOC IN GROUND WATER TRANSFORMED INTO A GASEOUS STATE BY A COUNTERCURRENT INDUCED-DRAFT TOWER	POTENTIALLY APPLICABLE
		ACTIVATED CARBON ADSORBTION	CARBON CAN READILY ABSORB MOST ORGANIC AND SOME INORGANICS FROM BOTH AQUEOUS AND AND GASEOUS PHASE	POTENTIALLY APPLICABLE
		ULTRAVIOLET(UV)/OXIDATION	DESTRUCTION OF COC THROUGH OXIDATION	REDUCED EFFECTIVENESS FOR SALINE WATER
	EX-SITU TREATMENT: CHEMICAL•	OXIDATION/REDUCTION	ELECTRONS TRANSFERRED TO A HIGHER OR LOWER STATE TO CREATE OXIDANTS WHICH CAN BE MORE EASILY HANDLED AND LESS TOXIC	COST PROHIBITIVE FOR LARGE VOLUME OF WATER
		INCINERATION	HIGH TEMPERATURE OXIDATION TO DESTROY ORGANIC COC IN LIQUIDS, GASSES, OR SOLIDS	COST PROHIBITIVE FOR LARGE VOLUME OF WATER
		ION EXCHANGE	EXCHANGE OF TARGET IONS WITH LESS HARMFUL IONS	INEFFECTIVE FOR SITE COC AND COST PROHIBITIVE FOR PRETREATMENT
	EX-SITU TREATMENT: BIOLOGICAL•	ANAEROBIC	DESTRUCTION OF CHLORINATED COC WITH ANAEROBIC BIOREACTOR	NOT EFFECTIVE FOR LARGE VOLUME OF WATER
		AEROBIC	DESTRUCTION OF CHLORINATED COC WITH AEROBIC BIOREACTOR	NOT EFFECTIVE FOR SITE COC

POTENTIAL OPTIONS

OPTIONS SCREENED OUT

• TO BE USED IN CONJUNCTION WITH GROUND-WATER [illegible]ACTION

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TABLE 2-10 (CONTINUED)

GENERAL RESPONSE ACTIONS	REMEDIAL TECHNOLOGY	PROCESS OPTIONS	DESCRIPTION	SCREENING COMMENTS
GROUND-WATER DISCHARGE ACTIONS	DISCHARGE	TO SURFACE WATER	DISCHARGE OF TREATED GROUND WATER TO BAY	POTENTIALLY APPLICABLE; NEED TO OBTAIN STATE APPROVAL
		TO POTW	DISCHARGE OF TREATED GROUND WATER TO LOCAL POTW OR SEWER MAIN	CLOSEST DISHARGE POINT IS MORE THAN ONE MILE AWAY
		REINJECTION	REINJECTION OF TREATED GROUND WATER INTO AQUIFER	OBTAINING PERMITS MAY BE DIFFICULT; NO NEED TO MAINTAIN AQUIFER YIELD

POTENTIAL OPTIONS

OPTIONS SCREENED OUT

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TABLE 3-1 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 1
NO ACTION

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Wetlands/ Water Resources (Federal)	Executive Order 11990; Wetlands Protection (40 CFR Part 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands.	The No Action alternative will not address potential impacts to wetlands from ground-water.

TABLE 3-2 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 2 DEED RESTRICTION AND LONG-TERM MONITORING

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Wetlands/ Water Resources (Federal)	Executive Order 11990; Wetlands Protection (40 CFR Part 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands.	The potential impacts to wetlands from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
	Executive Order 11988; Statement on Proceedings of Floodplain Management (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the occupancy and modifications of floodplains whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of floodplains.	The potential impacts to floodplains from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision-making processes which may impact water bodies, including wetlands.	If the implementation of remedial actions at Site 07 results in an impact to fish and/or wildlife, consultation with the U.S. Fish and Wildlife Service, RIDEM, and other federal and state agencies involved in fish and wildlife matters will be included.
	Clean Water Act, Section 404, 33 USC 1344; 40 CFR part 230	Applicable (or Relevant and Appropriate)	Prohibits the discharge of dredged or fill materials into a water of the U.S. if there is a practicable alternative.	Any impacts to wetlands will be minimized and mitigated.

TABLE 3-2 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 2 DEED RESTRICTION AND LONG-TERM MONITORING (Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Wetlands/ Water Resources (federal) (continued)	Rivers and Harbors Act, 33 USC 403; 33 CFR Parts 320-323	Relevant and Appropriate	Prohibits unauthorized obstruction or alteration of navigable waters.	The environmental standards in the Act will apply to any actions in tidal waters.
Wetlands (State)	Rhode Island Freshwater Wetlands Laws (RIGL 2-1-18 et seq.): RIDEM Rules Governing the Enforcement of the Freshwater Wetlands Act (CRIR 12-100-003)	Applicable	Defines and establishes provision for the protection of swamps, marshes, and other freshwater wetlands of the state. Actions are required to prevent the undesirable drainage, excavation, filling, alteration, encroachment, or any other form of disturbance to or destruction of a wetland.	The potential impacts to wetlands from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
Endangered Species (Federal)	Endangered Species Act of 1973 (16 U.S.C. 1531): Protection of Endangered Species	Relevant and Appropriate	Remedial actions may not jeopardize the continued existence of federally-listed endangered or threatened species, or adversely modify or destroy their critical habitats.	Information provided by RIDEM indicates that the Least Tern has been identified in the Davisville/Quonset area. If this species is identified at or adjacent to Site 07, then appropriate measures will be taken during remedial activities to ensure that the species and its habitat are not adversely affected.

TABLE 3-2 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 2 DEED RESTRICTION AND LONG-TERM MONITORING (Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Endangered Species (State)	Rhode Island Endangered Species Act (RIGL 20-37-1 et seq.)	Relevant and Appropriate	Remedial actions may not jeopardize the continued existence of state-listed endangered or threatened species, or adversely modify or destroy their critical habitats.	Information provided by RIDEM indicates that the Grasshopper Sparrow, the Upland Sandpiper, and the Least Tern have been identified in the Davisville/Quonset area. If any of these species are identified at Site 07, then appropriate measures will be taken during construction activities to ensure that the remedial action does not adversely affect the species or its habitat.
Coastal Zones (Federal)	Coastal Zone Management Act (16 USC 3501 et seq.)	Applicable	Must conduct activities in a manner consistent with the approved state management program.	The substantive requirements of this Act will be met.
Coastal Zones (State)	Rhode Island Coastal Resources Management Law (RIGL 46-23) and Regulations (CRIR 04-000-010)	Applicable	Creates the Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources. Requires demonstration that development or operation in coastal areas are consistent with the Coastal Resources Management Plan without significantly damaging the environment of the coastal region.	Because Site 07 is located in a coastal area, the Navy will coordinate with the CRMC, as appropriate, to ensure that any remedial actions which will affect the coastline of Calf Pasture Point are consistent with the Coastal Resources Management Plan to the maximum extent possible.

TABLE 3-2 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 2 DEED RESTRICTION AND LONG-TERM MONITORING (Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Historic Places (Federal)	Historical Preservation Act (16 USC 469 et seq.)	Applicable	Requires protection of significant scientific prehistorical, historical, or archaeological data. Must recover and preserve artifacts.	Portions of Site 07 have been identified as potential archaeologically-significant areas.
Historic Places (State)	Archaeological and Historic Preservation Act of 1974 (132 CFR 229 + 229.4): Protection of Archaeological and Historic Lands	Applicable	Restricts the use of land of unknown archaeological or historical significance.	Potential ARAR because portions of Site 07 have been identified as potential archaeologically-significant areas. Therefore, alternatives will be implemented in accordance with the substantive requirements of these regulations.

TABLE 3-3 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 2 DEED RESTRICTION AND LONG-TERM MONITORING

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Monitoring (Federal)	Resource Conservation and Recovery Act (RCRA), 42 USC 6901 et seq.	Relevant and Appropriate	Outlines specifications for the performance of hazardous waste storage, treatment, and disposal facilities.	Substantive RCRA requirements are to be met pertaining to wastes disposed of prior to 1980 and to RCRA-listed or characteristic waste generated during proposed monitoring activities.
	RCRA - Generator and Handler Requirements, 40 CFR 260-261	Relevant and Appropriate	Establishes standards for listing and identification of hazardous waste.	For any materials generated during monitoring well installation, hazardous waste determinations will be performed and the wastes will be managed in accordance with these regulations, if necessary.
	RCRA - Subpart F, 40 CFR 264.90 (Applicability) and Subpart G, 40 CFR 264.110 through 264.120 (Closure and Post Closure)	Relevant and Appropriate	Post-closure requirements for units where hazardous waste was disposed prior to 1982.	Monitoring standards will be met through the implementation of the long-term ground-water monitoring program.

TABLE 3-3 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 2 DEED RESTRICTION AND LONG-TERM MONITORING (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Monitoring (State)	Rules and Regulations for Ground-Water Quality (12-100-006)	Applicable	Rules and Regulations intended to protect and restore the quality of the state's ground water. Includes ground-water monitoring program requirements and monitoring well construction abandonment.	Ground-water monitoring program will comply with these regulations.
	Rhode Island Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.)	Relevant and Appropriate	Rules and regulations for hazardous waste generation, transportation, treatment, storage, and disposal. They incorporate, by reference, the federal RCRA requirements.	Wastes generated during monitoring activities will be managed in accordance with these regulations.

TABLE 3-3 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 2 DEED RESTRICTION AND LONG-TERM MONITORING (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Ground-Water Monitoring (Federal)	Clean Water Act (33 USC 1251-1376); Federal Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant and Appropriate	Standards established for the protection of human health and/or aquatic organisms.	AWQC, with modification, will be used during the development of performance standards for ground water based on the potential for discharge to surface water which may be used for fishing, boating, shellfish harvesting, and for wildlife habitat.
	Safe Drinking Water Act, 40 CFR Part 141	Relevant and Appropriate	Establishes enforceable Maximum Contaminant Levels (MCL) as standards for public drinking water systems. Used as cleanup standards for aquifers that are potential drinking water supplies. Establishes Maximum Contaminant Level Goals (MCLG) which are non-enforceable health goals for public drinking water systems. Non-zero MCLG are relevant and appropriate.	MCL and non-zero MCLG will be used during the development of performance standards for ground-water.

TABLE 3-3 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 2 DEED RESTRICTION AND LONG-TERM MONITORING (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Ground-Water Monitoring (State)	Rules and Regulations for Ground Water Quality (12-100-006)	Applicable	Establishes ground-water quality standards and/or requirements.	Will be used during the development of performance standards for ground-water.
	Water Pollution Control (RIGL 46-12 et seq) and Water Quality Standards and Ambient Water Quality Guidelines	Relevant and Appropriate	Establishes water use classifications and water quality criteria for all waters of the state. Establishes acute and chronic ambient water quality criteria for the protection of aquatic life.	Discharges of ground water from Site 07 to surface water will comply with the substantive portions of these regulations to the extent that they are more stringent than federal standards.
	Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases ("Remediation Regulations") (DEM-DSR-01-93, as amended Aug. 1996)	Applicable	Establishes Upper Concentration Limits (UCL) and methods for determining contaminant remediation criteria for Class GA and GB ground waters.	Substantive standard, to the extent which it is more stringent than federal standards, will be used during the development of performance standards for shallow and deep ground-water.

**TABLE 3-3 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 2
DEED RESTRICTION AND LONG-TERM MONITORING (Continued)**

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Sediment Monitoring (Federal)	Clean Water Act (33 USC 1251-1376; Federal Ambient Water Quality Criteria, 40 CFR 122.44	Relevant and Appropriate	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms.	Shoreline/offshore sediment is within the discharge area for Site 07 ground water. Therefore, if determined to be necessary during the long-term ground-water monitoring program, AWQC, with modification, will be used to develop performance standards for sediment.
Sediment Monitoring (State)	Water Pollution Control (RIGL 46-12 et seq.) and Water Quality Standards and Ambient Water Quality Guidelines	To Be Considered	Establishes water use classifications and water quality criteria for all waters of the state. Establishes acute and chronic ambient water quality criteria for the protection of aquatic life.	Shoreline/offshore sediment is within the discharge area for Site 07 ground water. Therefore, if determined to be necessary during the long-term ground-water monitoring program, Rhode Island ambient water quality guidelines will be considered for the development of performance standards for sediment.

TABLE 3-4 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 3 *IN-SITU* ANAEROBIC BIODEGRADATION

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Wetlands/ Water Resources (Federal)	Executive Order 11990; Wetlands Protection (40 CFR Part 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands.	The potential impacts to wetlands from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
	Executive Order 11988; Statement on Proceedings of Floodplain Management (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the occupancy and modifications of floodplains whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of floodplains.	The potential impacts to floodplains from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision-making processes which may impact water bodies, including wetlands.	If the implementation of remedial actions at Site 07 results in an impact to fish and/or wildlife, consultation with the U.S. Fish and Wildlife Service, RIDEM, and other federal and state agencies involved in fish and wildlife matters will be included.
	Clean Water Act, Section 404, 33 USC 1344; 40 CFR part 230	Applicable (or Relevant and Appropriate)	Prohibits the discharge of dredged or fill materials into a water of the U.S. if there is a practicable alternative.	Any impacts to wetlands will be minimized and mitigated.

TABLE 3-4 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 3 *IN-SITU* ANAEROBIC BIODEGRADATION(Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Wetlands/ Water Resources (federal) (continued)	Rivers and Harbors Act, 33 USC 403; 33 CFR Parts 320-323	Relevant and Appropriate	Prohibits unauthorized obstruction or alteration of navigable waters.	The environmental standards in the Act will apply to any actions in tidal waters.
Wetlands (State)	Rhode Island Freshwater Wetlands Laws (RIGL 2-1-18 et seq.): RIDEM Rules Governing the Enforcement of the Freshwater Wetlands Act (CRIR 12-100-003)	Applicable	Defines and establishes provision for the protection of swamps, marshes, and other freshwater wetlands of the state. Actions are required to prevent the undesirable drainage, excavation, filling, alteration, encroachment, or any other form of disturbance to or destruction of a wetland.	The potential impacts to wetlands from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
Endangered Species (Federal)	Endangered Species Act of 1973 (16 U.S.C. 1531): Protection of Endangered Species	Relevant and Appropriate	Remedial actions may not jeopardize the continued existence of federally-listed endangered or threatened species, or adversely modify or destroy their critical habitats.	Information provided by RIDEM indicates that the Least Tern has been identified in the Davisville/Quonset area. If this species is identified at or adjacent to Site 07, then appropriate measures will be taken during remedial activities to ensure that the species and its habitat are not adversely affected.

TABLE 3-4 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 3
***IN-SITU* ANAEROBIC BIODEGRADATION(Continued)**

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Endangered Species (State)	Rhode Island Endangered Species Act (RIGL 20-37-1 et seq.)	Relevant and Appropriate	Remedial actions may not jeopardize the continued existence of state-listed endangered or threatened species, or adversely modify or destroy their critical habitats.	Information provided by RIDEM indicates that the Grasshopper Sparrow, the Upland Sandpiper, and the Least Tern have been identified in the Davisville/Quonset area. If any of these species are identified at Site 07, then appropriate measures will be taken during construction activities to ensure that the remedial action does not adversely affect the species or its habitat.
Coastal Zones (Federal)	Coastal Zone Management Act (16 USC 3501 et seq.)	Applicable	Must conduct activities in a manner consistent with the approved state management program.	The substantive requirements of this Act will be met.
Coastal Zones (State)	Rhode Island Coastal Resources Management Law (RIGL 46-23) and Regulations (CRIR 04-000-010)	Applicable	Creates the Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources. Requires demonstration that development or operation in coastal areas are consistent with the Coastal Resources Management Plan without significantly damaging the environment of the coastal region.	Because Site 07 is located in a coastal area, the Navy will coordinate with the CRMC, as appropriate, to ensure that any remedial actions which will affect the coastline of Calf Pasture Point are consistent with the Coastal Resources Management Plan to the maximum extent possible.

TABLE 3-4 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 3
***IN-SITU* ANAEROBIC BIODEGRADATION(Continued)**

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Historic Places (Federal)	Historical Preservation Act (16 USC 469 et seq.)	Applicable	Requires protection of significant scientific prehistorical, historical, or archaeological data. Must recover and preserve artifacts.	Portions of Site 07 have been identified as potential archaeologically-significant areas.
Historic Places (State)	Archaeological and Historic Preservation Act of 1974 (132 CFR 229 + 229.4): Protection of Archaeological and Historic Lands	Applicable	Restricts the use of land of unknown archaeological or historical significance.	Potential ARAR because portions of Site 07 have been identified as potential archaeologically-significant areas. Therefore, alternatives will be implemented in accordance with the substantive requirements of these regulations.

TABLE 3-5 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 3
***IN-SITU* ANAEROBIC BIODEGRADATION**

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
In-Situ Treatment (Federal)	RCRA - Subpart Q - Chemical, Physical, and Biological Units, 40 CFR 265.400 through 265.406	Relevant and Appropriate	Establishes standards for utilizing biological treatment in order to protect human health or the environment.	Remedial systems will be designed and operated to meet the substantive provisions of the regulations.
In-Situ Treatment (State)	Rhode Island Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.)			
	Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases ("Remediation Regulations") (DEM-DSR-01-93, as amended Aug. 1996)	Applicable	Rules and regulations for the investigation and remediation of hazardous materials. Establishes clean-up standards and Upper Concentration Limits (UCL) for hazardous wastes in soil and ground water.	Remedial systems will be designed and operated in accordance with these requirements. Clean-up standards and UCL will be used for the development of performance standards.

TABLE 3-5 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 3
***IN-SITU* ANAEROBIC BIODEGRADATION (Continued)**

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Monitoring (Federal)	Resource Conservation and Recovery Act (RCRA), 42 USC 6901 et seq.	Relevant and Appropriate	Outlines specifications for the performance of hazardous waste storage, treatment, and disposal facilities.	Substantive RCRA requirements are to be met pertaining to wastes disposed of prior to 1980 and to RCRA-listed or characteristic waste generated during proposed monitoring activities.
	RCRA - Generator and Handler Requirements, 40 CFR 260-261	Relevant and Appropriate	Establishes standards for listing and identification of hazardous waste.	For any materials generated during monitoring well installation, hazardous waste determinations will be performed and the wastes will be managed in accordance with these regulations, if necessary.
	RCRA - Subpart F, 40 CFR 264.90 (Applicability) and Subpart G, 40 CFR 264.110 through 264.120 (Closure and Post Closure)	Relevant and Appropriate	Post-closure requirements for units where hazardous waste was disposed prior to 1982.	Monitoring standards will be met through the implementation of the long-term ground-water monitoring program.

TABLE 3-5 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 3
***IN-SITU* ANAEROBIC BIODEGRADATION (Continued)**

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Monitoring (State)	Rules and Regulations for Ground-Water Quality (12-100-006)	Applicable	Rules and Regulations intended to protect and restore the quality of the state's ground water. Includes ground-water monitoring program requirements and monitoring well construction abandonment.	Ground-water monitoring program will comply with these regulations.
	Rhode Island Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.)	Relevant and Appropriate	Rules and regulations for hazardous waste generation, transportation, treatment, storage, and disposal. They incorporate, by reference, the federal RCRA requirements.	Wastes generated during monitoring activities will be managed in accordance with these regulations.

TABLE 3-5 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 3 *IN-SITU* ANAEROBIC BIODEGRADATION (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Ground-Water Monitoring (Federal)	Clean Water Act (33 USC 1251-1376); Federal Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant and Appropriate	Non-enforceable standards established for the protection of human health and/or aquatic organisms.	AWQC, with modification, will be used during the development of performance standards for ground water based on the potential for discharge to surface water which may be used for fishing, boating, shellfish harvesting, and for wildlife habitat.
	Safe Drinking Water Act, 40 CFR Part 141	Relevant and Appropriate	Establishes enforceable Maximum Contaminant Levels (MCL) as standards for public drinking water systems. Used as cleanup standards for aquifers that are potential drinking water supplies. Establishes Maximum Contaminant Level Goals (MCLG) which are non-enforceable health goals for public drinking water systems. Non-zero MCLG are relevant and appropriate.	MCL and non-zero MCLG will be used during the development of performance standards for ground-water.

TABLE 3-5 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 3 *IN-SITU* ANAEROBIC BIODEGRADATION (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Ground-Water Monitoring (State)	Rules and Regulations for Ground Water Quality (12-100-006)	Applicable	Establishes ground-water quality standards and/or requirements.	Will be used during the development of performance standards for ground-water.
	Water Pollution Control (RIGL 46-12 et seq) and Water Quality Standards and Ambient Water Quality Guidelines	Relevant and Appropriate	Establishes water use classifications and water quality criteria for all waters of the state. Establishes acute and chronic ambient water quality criteria for the protection of aquatic life.	Discharges of ground water from Site 07 to surface water will comply with the substantive portions of these regulations to the extent that they are more stringent than federal standards.
	Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases ("Remediation Regulations") (DEM-DSR-01-93, as amended Aug. 1996)	Applicable	Establishes Upper Concentration Limits (UCL) and methods for determining contaminant remediation criteria for Class GA and GB ground waters.	Substantive standard, to the extent which it is more stringent than federal standards, will be used during the development of performance standards for shallow and deep ground-water.

TABLE 3-5 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 3 *IN-SITU* ANAEROBIC BIODEGRADATION (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Sediment Monitoring (Federal)	Clean Water Act (33 USC 1251-1376; Federal Ambient Water Quality Criteria, 40 CFR 122.44	Relevant and Appropriate	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms.	Shoreline/offshore sediment is within the discharge area for Site 07 ground water. Therefore, if determined to be necessary during the long-term ground-water monitoring program, AWQC, with modification, will be used to develop performance standards for sediment.
Sediment Monitoring (State)	Water Pollution Control (RIGL 46-12 et seq.) and Water Quality Standards and Ambient Water Quality Guidelines	To Be Considered	Establishes water use classifications and water quality criteria for all waters of the state. Establishes acute and chronic ambient water quality criteria for the protection of aquatic life.	Shoreline/offshore sediment is within the discharge area for Site 07 ground water. Therefore, if determined to be necessary during the long-term ground-water monitoring program, Rhode Island ambient water quality guidelines will be considered for the development of performance standards for sediment.

TABLE 3-6 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Wetlands/ Water Resources (Federal)	Executive Order 11990; Wetlands Protection (40 CFR Part 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands.	The potential impacts to wetlands from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
	Executive Order 11988; Statement on Proceedings of Floodplain Management (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the occupancy and modifications of floodplains whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of floodplains.	The potential impacts to floodplains from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision-making processes which may impact water bodies, including wetlands.	If the implementation of remedial actions at Site 07 results in an impact to fish and/or wildlife, consultation with the U.S. Fish and Wildlife Service, RIDEM, and other federal and state agencies involved in fish and wildlife matters will be included.
	Clean Water Act, Section 404, 33 USC 1344; 40 CFR part 230	Applicable (or Relevant and Appropriate)	Prohibits the discharge of dredged or fill materials into a water of the U.S. if there is a practicable alternative.	Any impacts to wetlands will be minimized and mitigated.

TABLE 3-6 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS (Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Wetlands/ Water Resources (federal) (continued)	Rivers and Harbors Act, 33 USC 403; 33 CFR Parts 320-323	Relevant and Appropriate	Prohibits unauthorized obstruction or alteration of navigable waters.	The environmental standards in the Act will apply to any actions in tidal waters.
Wetlands (State)	Rhode Island Freshwater Wetlands Laws (RIGL 2-1-18 et seq.): RIDEM Rules Governing the Enforcement of the Freshwater Wetlands Act (CRIR 12-100-003)	Applicable	Defines and establishes provision for the protection of swamps, marshes, and other freshwater wetlands of the state. Actions are required to prevent the undesirable drainage, excavation, filling, alteration, encroachment, or any other form of disturbance to or destruction of a wetland.	The potential impacts to wetlands from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
Endangered Species (Federal)	Endangered Species Act of 1973 (16 U.S.C. 1531): Protection of Endangered Species	Relevant and Appropriate	Remedial actions may not jeopardize the continued existence of federally-listed endangered or threatened species, or adversely modify or destroy their critical habitats.	Information provided by RIDEM indicates that the Least Tern has been identified in the Davisville/Quonset area. If this species is identified at or adjacent to Site 07, then appropriate measures will be taken during remedial activities to ensure that the species and its habitat are not adversely affected.

TABLE 3-6 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS (Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Endangered Species (State)	Rhode Island Endangered Species Act (RIGL 20-37-1 et seq.)	Relevant and Appropriate	Remedial actions may not jeopardize the continued existence of state-listed endangered or threatened species, or adversely modify or destroy their critical habitats.	Information provided by RIDEM indicates that the Grasshopper Sparrow, the Upland Sandpiper, and the Least Tern have been identified in the Davisville/Quonset area. If any of these species are identified at Site 07, then appropriate measures will be taken during construction activities to ensure that the remedial action does not adversely affect the species or its habitat.
Coastal Zones (Federal)	Coastal Zone Management Act (16 USC 3501 et seq.)	Applicable	Must conduct activities in a manner consistent with the approved state management program.	The substantive requirements of this Act will be met.
Coastal Zones (State)	Rhode Island Coastal Resources Management Law (RIGL 46-23) and Regulations (CRIR 04-000-010)	Applicable	Creates the Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources. Requires demonstration that development or operation in coastal areas are consistent with the Coastal Resources Management Plan without significantly damaging the environment of the coastal region.	Because Site 07 is located in a coastal area, the Navy will coordinate with the CRMC, as appropriate, to ensure that any remedial actions which will affect the coastline of Calf Pasture Point are consistent with the Coastal Resources Management Plan to the maximum extent possible.

TABLE 3-6 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS (Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Historic Places (Federal)	Historical Preservation Act (16 USC 469 et seq.)	Applicable	Requires protection of significant scientific prehistorical, historical, or archaeological data. Must recover and preserve artifacts.	Portions of Site 07 have been identified as potential archaeologically-significant areas.
Historic Places (State)	Archaeological and Historic Preservation Act of 1974 (132 CFR 229 + 229.4): Protection of Archaeological and Historic Lands	Applicable	Restricts the use of land of unknown archaeological or historical significance.	Potential ARAR because portions of Site 07 have been identified as potential archaeologically-significant areas. Therefore, alternatives will be implemented in accordance with the substantive requirements of these regulations.

TABLE 3-7 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Monitoring (Federal)	Resource Conservation and Recovery Act (RCRA), 42 USC 6901 et seq.	Relevant and Appropriate	Outlines specifications for the performance of hazardous waste storage, treatment, and disposal facilities.	Substantive RCRA requirements are to be met pertaining to wastes disposed of prior to 1980 and to RCRA-listed or characteristic waste generated during proposed monitoring activities.
	RCRA - Generator and Handler Requirements, 40 CFR 260-261	Relevant and Appropriate	Establishes standards for listing and identification of hazardous waste.	For any materials generated during monitoring well installation, hazardous waste determinations will be performed and the wastes will be managed in accordance with these regulations, if necessary.
	RCRA - Subpart F, 40 CFR 264.90 (Applicability) and Subpart G, 40 CFR 264.110 through 264.120 (Closure and Post Closure)	Relevant and Appropriate	Post-closure requirements for units where hazardous waste was disposed prior to 1982.	Monitoring standards will be met through the implementation of the long-term ground-water monitoring program.

TABLE 3-7 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Monitoring (State)	Rules and Regulations for Ground-Water Quality (12-100-006)	Applicable	Rules and Regulations intended to protect and restore the quality of the state's ground water. Includes ground-water monitoring program requirements and monitoring well construction abandonment.	Ground-water monitoring program will comply with these regulations.
	Rhode Island Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.)	Relevant and Appropriate	Rules and regulations for hazardous waste generation, transportation, treatment, storage, and disposal. They incorporate, by reference, the federal RCRA requirements.	Wastes generated during monitoring activities will be managed in accordance with these regulations.

TABLE 3-7 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Ground-Water Monitoring (Federal)	Clean Water Act (33 USC 1251-1376); Federal Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant and Appropriate	Non-enforceable standards established for the protection of human health and/or aquatic organisms.	AWQC, with modification, will be used during the development of performance standards for ground water based on the potential for discharge to surface water which may be used for fishing, boating, shellfish harvesting, and for wildlife habitat.
	Safe Drinking Water Act, 40 CFR Part 141	Relevant and Appropriate	Establishes enforceable Maximum Contaminant Levels (MCL) as standards for public drinking water systems. Used as cleanup standards for aquifers that are potential drinking water supplies. Establishes Maximum Contaminant Level Goals (MCLG) which are non-enforceable health goals for public drinking water systems. Non-zero MCLG are relevant and appropriate.	MCL and non-zero MCLG will be used during the development of performance standards for ground-water.

TABLE 3-7 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Ground-Water Monitoring (State)	Rules and Regulations for Ground Water Quality (12-100-006)	Applicable	Establishes ground-water quality standards and/or requirements.	Will be used during the development of performance standards for ground-water.
	Water Pollution Control (RIGL 46-12 et seq) and Water Quality Standards and Ambient Water Quality Guidelines	Relevant and Appropriate	Establishes water use classifications and water quality criteria for all waters of the state. Establishes acute and chronic ambient water quality criteria for the protection of aquatic life.	Discharges of ground water from Site 07 to surface water will comply with the substantive portions of these regulations to the extent that they are more stringent than federal standards.
	Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases ("Remediation Regulations") (DEM-DSR-01-93, as amended Aug. 1996)	Applicable	Establishes Upper Concentration Limits (UCL) and methods for determining contaminant remediation criteria for Class GA and GB ground waters.	Substantive standard, to the extent which it is more stringent than federal standards, will be used during the development of performance standards for shallow and deep ground-water.

**TABLE 3-7 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 4
VACUUM-VAPORIZER WELLS (Continued)**

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Sediment Monitoring (Federal)	Clean Water Act (33 USC 1251-1376; Federal Ambient Water Quality Criteria, 40 CFR 122.44	Relevant and Appropriate	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms.	Shoreline/offshore sediment is within the discharge area for Site 07 ground water. Therefore, if determined to be necessary during the long-term ground-water monitoring program, AWQC, with modification, will be used to develop performance standards for sediment.
Sediment Monitoring (State)	Water Pollution Control (RIGL 46-12 et seq.) and Water Quality Standards and Ambient Water Quality Guidelines	To Be Considered	Establishes water use classifications and water quality criteria for all waters of the state. Establishes acute and chronic ambient water quality criteria for the protection of aquatic life.	Shoreline/offshore sediment is within the discharge area for Site 07 ground water. Therefore, if determined to be necessary during the long-term ground-water monitoring program, Rhode Island ambient water quality guidelines will be considered for the development of performance standards for sediment.
Onsite Treatment (Federal)	RCRA (40 CFR 262) Generator Requirements for Manifesting Waste for Offsite Disposal	Relevant and Appropriate	Standards for manifesting, marking, and recording hazardous waste shipments for offsite treatment/ disposal.	If treatment system by-products require offsite treatment/disposal, then generator requirements will be followed.
	RCRA (40 CFR 264) Subpart I Use and Management of Containers	Relevant and Appropriate	Outlines use and management standards applicable to owners and operators of all hazardous waste facilities that store containers of hazardous waste.	If treatment system by-products require storage of hazardous waste in containers, then management procedures will comply with these requirements.

TABLE 3-7 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Onsite Treatment/ Disposal (State)	Rhode Island Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.)			
	Hazardous Waste Management Rules and Regulations	Relevant and Appropriate	Rules and regulations for hazardous waste generation, transportation, treatment, storage, and disposal.	If treatment system by-products are determined to be hazardous, then these requirements will be met.
	Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases ("Remediation Regulations") (DEM-DSR-01-93, as amended Aug. 1996)	Applicable	Rules and regulations for the investigation and remediation of hazardous materials. Establishes clean-up standards and Upper Concentration Limits (UCL) for hazardous wastes in soil and ground water.	Remedial systems will be designed and operated in accordance with these requirements. Clean-up standards and UCL will be used for the development of performance standards.
	Rhode Island Refuse Disposal Law (23-18.9) Rules and Regulations for Solid Waste Management Facilities (DEM-0WM-SW01-97)	Relevant and Appropriate	Rules and regulations for solid waste management facilities.	These requirements will be met if the treatment system by-products require management as a solid waste.

TABLE 3-7 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Venting/ Discharges to Air (Federal)	Clean Air Act (40 CFR 61) National Emissions Standards for Hazardous Pollutants (NESHAPS)	Applicable	Establishes emissions limitations for hazardous air pollutants and sets forth regulated sources of those pollutants.	System offgas will be treated, as necessary, to meet these regulations.
	RCRA 40 CFR 264.1030 - 264.1036 Subpart AA - Air Emission Standards for Process Vents	Applicable	Establishes standards for air emissions from process vents associated with distillation, fractionation, thin film evaporation, column extraction, or air stream stripping operations that treat RCRA substances and have a total organic concentration of 10 ppm or greater.	System offgas will be treated, as necessary, to meet these regulations.
Venting/ Discharges to Air (State)	Rhode Island Clean Air Act (RIGL Title 23 Chapter 23) General Air Quality and Air Emissions Requirements	Applicable	Sets emission limitations for particulates and visible air pollutants.	System offgas will be treated, as necessary, to meet these requirements.

TABLE 3-7 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
	Rhode Island Clean Air Act (RIGL Title 23 Chapter 23) General Air Quality and Air Emissions Requirements			
	Air Pollution Control Regulations, RIDoH, Div. of Air Pollution Control, as amended 5/20/1991			
	- Regulation No.1 - Visible Emissions	Applicable	No air contaminant emissions will be allowed for more than 3 minutes in any one hour which are greater than or equal to 20% opacity.	Offgas system will be treated, as necessary, to meet these requirements.
	- Regulation No.5 - Fugitive Dust	Applicable	Requires that reasonable precaution be taken to prevent particulate matter from becoming airborne.	Onsite remedial actions will use good industrial practices to prevent particulate matter from becoming airborne.
	- Regulation No.7 - Emissions Detrimental to Person or Property	Applicable	Prohibits emissions of pollutants which may be injurious to human, plant, or animal life or cause damage to property or which reasonably interferes with the enjoyment of life and property.	All emissions will meet this requirement or gas treatment will be used, as necessary.

TABLE 3-7 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 4 VACUUM-VAPORIZER WELLS (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
	- Regulation No.9 - Approval to Construct, Install, Modify, or Operate	Applicable	Establishes guidelines for the construction, installation, modification, or operation of potential air emission units. Establishes permissible emission rates.	Construction, installation, modification, or operation of the offgas system will meet these requirements.
	- Regulation No.15 - Control of Organic Solvent Emissions	Applicable	Limits the amount of organic solvents emitted to the atmosphere.	Treatment of the offgas will be used, as necessary, to meet these requirements.
	- Regulation No.17 - Odors	Applicable	Prohibits the release of objectionable odors across property lines.	No remedial action or air emissions will emit objectionable odors beyond the facility boundary, as practicable.
	- Regulation No. 22 - Air Toxics	Applicable	Prohibits the emission of specified pollutants at rates which would result in ground level concentrations greater than acceptable ambient levels or acceptable ambient levels with LAER, as set in the regulation.	If air emissions contain regulated substances, then air emissions control equipment will be used, as necessary, to meet these requirements.

TABLE 3-8 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 5 *IN-SITU* PERMEABLE REACTION WALL

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Wetlands/ Water Resources (Federal)	Executive Order 11990; Wetlands Protection (40 CFR Part 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands.	The potential impacts to wetlands from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
	Executive Order 11988; Statement on Proceedings of Floodplain Management (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the occupancy and modifications of floodplains whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of floodplains.	The potential impacts to floodplains from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision-making processes which may impact water bodies, including wetlands.	If the implementation of remedial actions at Site 07 results in an impact to fish and/or wildlife, consultation with the U.S. Fish and Wildlife Service, RIDEM, and other federal and state agencies involved in fish and wildlife matters will be included.
	Clean Water Act, Section 404, 33 USC 1344; 40 CFR part 230	Applicable (or Relevant and Appropriate)	Prohibits the discharge of dredged or fill materials into a water of the U.S. if there is a practicable alternative.	Any impacts to wetlands will be minimized and mitigated.

TABLE 3-8 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 5 *IN-SITU* PERMEABLE REACTION WALL (Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Wetlands/ Water Resources (federal) (continued)	Rivers and Harbors Act, 33 USC 403; 33 CFR Parts 320-323	Relevant and Appropriate	Prohibits unauthorized obstruction or alteration of navigable waters.	The environmental standards in the Act will apply to any actions in tidal waters.
Wetlands (State)	Rhode Island Freshwater Wetlands Laws (RIGL 2-1-18 et seq.): RIDEM Rules Governing the Enforcement of the Freshwater Wetlands Act (CRIR 12-100-003)	Applicable	Defines and establishes provision for the protection of swamps, marshes, and other freshwater wetlands of the state. Actions are required to prevent the undesirable drainage, excavation, filling, alteration, encroachment, or any other form of disturbance to or destruction of a wetland.	The potential impacts to wetlands from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
Endangered Species (Federal)	Endangered Species Act of 1973 (16 U.S.C. 1531): Protection of Endangered Species	Relevant and Appropriate	Remedial actions may not jeopardize the continued existence of federally-listed endangered or threatened species, or adversely modify or destroy their critical habitats.	Information provided by RIDEM indicates that the Least Tern has been identified in the Davisville/Quonset area. If this species is identified at or adjacent to Site 07, then appropriate measures will be taken during remedial activities to ensure that the species and its habitat are not adversely affected.

TABLE 3-8 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 5
***IN-SITU* PERMEABLE REACTION WALL (Continued)**

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Endangered Species (State)	Rhode Island Endangered Species Act (RIGL 20-37-1 et seq.)	Relevant and Appropriate	Remedial actions may not jeopardize the continued existence of state-listed endangered or threatened species, or adversely modify or destroy their critical habitats.	Information provided by RIDEM indicates that the Grasshopper Sparrow, the Upland Sandpiper, and the Least Tern have been identified in the Davisville/Quonset area. If any of these species are identified at Site 07, then appropriate measures will be taken during construction activities to ensure that the remedial action does not adversely affect the species or its habitat.
Coastal Zones (Federal)	Coastal Zone Management Act (16 USC 3501 et seq.)	Applicable	Must conduct activities in a manner consistent with the approved state management program.	The substantive requirements of this Act will be met.
Coastal Zones (State)	Rhode Island Coastal Resources Management Law (RIGL 46-23) and Regulations (CRIR 04-000-010)	Applicable	Creates the Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources. Requires demonstration that development or operation in coastal areas are consistent with the Coastal Resources Management Plan without significantly damaging the environment of the coastal region.	Because Site 07 is located in a coastal area, the Navy will coordinate with the CRMC, as appropriate, to ensure that any remedial actions which will affect the coastline of Calf Pasture Point are consistent with the Coastal Resources Management Plan to the maximum extent possible.

TABLE 3-8 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 5 *IN-SITU* PERMEABLE REACTION WALL (Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Historic Places (Federal)	Historical Preservation Act (16 USC 469 et seq.)	Applicable	Requires protection of significant scientific prehistorical, historical, or archaeological data. Must recover and preserve artifacts.	Portions of Site 07 have been identified as potential archaeologically-significant areas.
Historic Places (State)	Archaeological and Historic Preservation Act of 1974 (132 CFR 229 + 229.4): Protection of Archaeological and Historic Lands	Applicable	Restricts the use of land of unknown archaeological or historical significance.	Potential ARAR because portions of Site 07 have been identified as potential archaeologically-significant areas. Therefore, alternatives will be implemented in accordance with the substantive requirements of these regulations.

TABLE 3-9 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 5 *IN-SITU* PERMEABLE REACTION WALL

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
In-Situ Treatment (Federal)	RCRA - Subpart Q - Chemical, Physical, and Biological Units, 40 CFR 265.400 through 265.406	Relevant and Appropriate	Establishes standards for utilizing physical/chemical treatment in order to protect human health or the environment.	Remedial systems will be designed and operated to meet the substantive provisions of the regulations.
In-Situ Treatment (State)	Rhode Island Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.)			
	Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases ("Remediation Regulations") (DEM-DSR-01-93, as amended Aug, 1996)	Applicable	Rules and regulations for the investigation and remediation of hazardous materials. Establishes clean-up standards and Upper Concentration Limits (UCL) for hazardous wastes in soil and ground water.	Remedial systems will be designed and operated in accordance with these requirements. Clean-up standards and UCL will be used for the development of performance standards.

TABLE 3-9 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 5
***IN-SITU* PERMEABLE REACTION WALL (Continued)**

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Monitoring (Federal)	Resource Conservation and Recovery Act (RCRA), 42 USC 6901 et seq.	Relevant and Appropriate	Outlines specifications for the performance of hazardous waste storage, treatment, and disposal facilities.	Substantive RCRA requirements are to be met pertaining to wastes disposed of prior to 1980 and to RCRA-listed or characteristic waste generated during proposed monitoring activities.
	RCRA - Generator and Handler Requirements, 40 CFR 260-261	Relevant and Appropriate	Establishes standards for listing and identification of hazardous waste.	For any materials generated during monitoring well installation, hazardous waste determinations will be performed and the wastes will be managed in accordance with these regulations, if necessary.
	RCRA - Subpart F, 40 CFR 264.90 (Applicability) and Subpart G, 40 CFR 264.110 through 264.120 (Closure and Post Closure)	Relevant and Appropriate	Post-closure requirements for units where hazardous waste was disposed prior to 1982.	Monitoring standards will be met through the implementation of the long-term ground-water monitoring program.

TABLE 3-9 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 5
***IN-SITU* PERMEABLE REACTION WALL (Continued)**

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Monitoring (State)	Rules and Regulations for Ground-Water Quality (12-100-006)	Applicable	Rules and Regulations intended to protect and restore the quality of the state's ground water. Includes ground-water monitoring program requirements and monitoring well construction abandonment.	Ground-water monitoring program will comply with these regulations.
	Rhode Island Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.)	Relevant and Appropriate	Rules and regulations for hazardous waste generation, transportation, treatment, storage, and disposal. They incorporate, by reference, the federal RCRA requirements.	Wastes generated during monitoring activities will be managed in accordance with these regulations.

TABLE 3-9 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 5 *IN-SITU* PERMEABLE REACTION WALL (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Ground-Water Monitoring (Federal)	Clean Water Act (33 USC 1251-1376); Federal Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant and Appropriate	Non-enforceable standards established for the protection of human health and/or aquatic organisms.	AWQC, with modification, will be used during the development of performance standards for ground water based on the potential for discharge to surface water which may be used for fishing, boating, shellfish harvesting, and for wildlife habitat.
	Safe Drinking Water Act, 40 CFR Part 141	Relevant and Appropriate	Establishes enforceable Maximum Contaminant Levels (MCL) as standards for public drinking water systems. Used as cleanup standards for aquifers that are potential drinking water supplies. Establishes Maximum Contaminant Level Goals (MCLG) which are non-enforceable health goals for public drinking water systems. Non-zero MCLG are relevant and appropriate.	MCL and non-zero MCLG will be used during the development of performance standards for ground-water.

TABLE 3-9 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 5 *IN-SITU* PERMEABLE REACTION WALL (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Ground-Water Monitoring (State)	Rules and Regulations for Ground Water Quality (12-100-006)	Applicable	Establishes ground-water quality standards and/or requirements.	Will be used during the development of performance standards for ground-water.
	Water Pollution Control (RIGL 46-12 et seq) and Water Quality Standards and Ambient Water Quality Guidelines	Relevant and Appropriate	Establishes water use classifications and water quality criteria for all waters of the state. Establishes acute and chronic ambient water quality criteria for the protection of aquatic life.	Discharges of ground water from Site 07 to surface water will comply with the substantive portions of these regulations to the extent that they are more stringent than federal standards.
	Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases ("Remediation Regulations") (DEM-DSR-01-93, as amended Aug. 1996)	Applicable	Establishes Upper Concentration Limits (UCL) and methods for determining contaminant remediation criteria for Class GA and GB ground waters.	Substantive standard, to the extent which it is more stringent than federal standards, will be used during the development of performance standards for shallow and deep ground-water.

TABLE 3-9 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 5 *IN-SITU* PERMEABLE REACTION WALL (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Sediment Monitoring (Federal)	Clean Water Act (33 USC 1251-1376; Federal Ambient Water Quality Criteria, 40 CFR 122.44	Relevant and Appropriate	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms.	Shoreline/offshore sediment is within the discharge area for Site 07 ground water. Therefore, if determined to be necessary during the long-term ground-water monitoring program, AWQC, with modification, will be used to develop performance standards for sediment.
Sediment Monitoring (State)	Water Pollution Control (RIGL 46-12 et seq.) and Water Quality Standards and Ambient Water Quality Guidelines	To Be Considered	Establishes water use classifications and water quality criteria for all waters of the state. Establishes acute and chronic ambient water quality criteria for the protection of aquatic life.	Shoreline/offshore sediment is within the discharge area for Site 07 ground water. Therefore, if determined to be necessary during the long-term ground-water monitoring program, Rhode Island ambient water quality guidelines will be considered for the development of performance standards for sediment.

TABLE 3-10 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Wetlands/ Water Resources (Federal)	Executive Order 11990; Wetlands Protection (40 CFR Part 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands.	The potential impacts to wetlands from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
	Executive Order 11988; Statement on Proceedings of Floodplain Management (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the occupancy and modifications of floodplains whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of floodplains.	The potential impacts to floodplains from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
	Fish and Wildlife Coordination Act of 1958 (16 U.S.C. 661) Protection of Wildlife Habitats	Applicable	Requires consultation with federal and state conservation agencies during planning and decision-making processes which may impact water bodies, including wetlands.	If the implementation of remedial actions at Site 07 results in an impact to fish and/or wildlife, consultation with the U.S. Fish and Wildlife Service, RIDEM, and other federal and state agencies involved in fish and wildlife matters will be included.
	Clean Water Act, Section 404, 33 USC 1344; 40 CFR part 230	Applicable (or Relevant and Appropriate)	Prohibits the discharge of dredged or fill materials into a water of the U.S. if there is a practicable alternative.	Any impacts to wetlands will be minimized and mitigated.

TABLE 3-10 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING(Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Wetlands/ Water Resources (federal) (continued)	Rivers and Harbors Act, 33 USC 403; 33 CFR Parts 320-323	Relevant and Appropriate	Prohibits unauthorized obstruction or alteration of navigable waters.	The environmental standards in the Act will apply to any actions in tidal waters.
Wetlands (State)	Rhode Island Freshwater Wetlands Laws (RIGL 2-1-18 et seq.): RIDEM Rules Governing the Enforcement of the Freshwater Wetlands Act (CRIR 12-100-003)	Applicable	Defines and establishes provision for the protection of swamps, marshes, and other freshwater wetlands of the state. Actions are required to prevent the undesirable drainage, excavation, filling, alteration, encroachment, or any other form of disturbance to or destruction of a wetland.	The potential impacts to wetlands from remedial actions at Site 07 will be avoided, to the extent possible, and minimized in accordance with these requirements.
Endangered Species (Federal)	Endangered Species Act of 1973 (16 U.S.C. 1531): Protection of Endangered Species	Relevant and Appropriate	Remedial actions may not jeopardize the continued existence of federally-listed endangered or threatened species, or adversely modify or destroy their critical habitats.	Information provided by RIDEM indicates that the Least Tern has been identified in the Davisville/Quonset area. If this species is identified at or adjacent to Site 07, then appropriate measures will be taken during remedial activities to ensure that the species and its habitat are not adversely affected.

TABLE 3-10 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING(Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Endangered Species (State)	Rhode Island Endangered Species Act (RIGL 20-37-1 et seq.)	Relevant and Appropriate	Remedial actions may not jeopardize the continued existence of state-listed endangered or threatened species, or adversely modify or destroy their critical habitats.	Information provided by RIDEM indicates that the Grasshopper Sparrow, the Upland Sandpiper, and the Least Tern have been identified in the Davisville/Quonset area. If any of these species are identified at Site 07, then appropriate measures will be taken during construction activities to ensure that the remedial action does not adversely affect the species or its habitat.
Coastal Zones (Federal)	Coastal Zone Management Act (16 USC 3501 et seq.)	Applicable	Must conduct activities in a manner consistent with the approved state management program.	The substantive requirements of this Act will be met.
Coastal Zones (State)	Rhode Island Coastal Resources Management Law (RIGL 46-23) and Regulations (CRIR 04-000-010)	Applicable	Creates the Coastal Resources Management Council and sets standards and authorizes promulgation of regulations for management and protection of coastal resources. Requires demonstration that development or operation in coastal areas are consistent with the Coastal Resources Management Plan without significantly damaging the environment of the coastal region.	Because Site 07 is located in a coastal area, the Navy will coordinate with the CRMC, as appropriate, to ensure that any remedial actions which will affect the coastline of Calf Pasture Point are consistent with the Coastal Resources Management Plan to the maximum extent possible.

TABLE 3-10 LOCATION-SPECIFIC ARARs FOR ALTERNATIVE 6
GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING(Continued)

Media	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Historic Places (Federal)	Historical Preservation Act (16 USC 469 et seq.)	Applicable	Requires protection of significant scientific prehistorical, historical, or archaeological data. Must recover and preserve artifacts.	Portions of Site 07 have been identified as potential archaeologically-significant areas.
Historic Places (State)	Archaeological and Historic Preservation Act of 1974 (132 CFR 229 + 229.4): Protection of Archaeological and Historic Lands	Applicable	Restricts the use of land of unknown archaeological or historical significance.	Potential ARAR because portions of Site 07 have been identified as potential archaeologically-significant areas. Therefore, alternatives will be implemented in accordance with the substantive requirements of these regulations.

TABLE 3-11 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Monitoring (Federal)	Resource Conservation and Recovery Act (RCRA), 42 USC 6901 et seq.	Relevant and Appropriate	Outlines specifications for the performance of hazardous waste storage, treatment, and disposal facilities.	Substantive RCRA requirements are to be met pertaining to wastes disposed of prior to 1980 and to RCRA-listed or characteristic waste generated during proposed monitoring activities.
	RCRA - Generator and Handler Requirements, 40 CFR 260-261	Relevant and Appropriate	Establishes standards for listing and identification of hazardous waste.	For any materials generated during monitoring well installation, hazardous waste determinations will be performed and the wastes will be managed in accordance with these regulations, if necessary.
	RCRA - Subpart F, 40 CFR 264.90 (Applicability) and Subpart G, 40 CFR 264.110 through 264.120 (Closure and Post Closure)	Relevant and Appropriate	Post-closure requirements for units where hazardous waste was disposed prior to 1982.	Monitoring standards will be met through the implementation of the long-term ground-water monitoring program.

TABLE 3-11 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Monitoring (State)	Rules and Regulations for Ground-Water Quality (12-100-006)	Applicable	Rules and Regulations intended to protect and restore the quality of the state's ground water. Includes ground-water monitoring program requirements and monitoring well construction abandonment.	Ground-water monitoring program will comply with these regulations.
	Rhode Island Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.)	Relevant and Appropriate	Rules and regulations for hazardous waste generation, transportation, treatment, storage, and disposal. They incorporate, by reference, the federal RCRA requirements.	Wastes generated during monitoring activities will be managed in accordance with these regulations.

TABLE 3-11 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Ground-Water Monitoring (Federal)	Clean Water Act (33 USC 1251-1376); Federal Ambient Water Quality Criteria (AWQC), 40 CFR 122.44	Relevant and Appropriate	Non-enforceable standards established for the protection of human health and/or aquatic organisms.	AWQC, with modification, will be used during the development of performance standards for ground water based on the potential for discharge to surface water which may be used for fishing, boating, shellfish harvesting, and for wildlife habitat.
	Safe Drinking Water Act, 40 CFR Part 141	Relevant and Appropriate	Establishes enforceable Maximum Contaminant Levels (MCL) as standards for public drinking water systems. Used as cleanup standards for aquifers that are potential drinking water supplies. Establishes Maximum Contaminant Level Goals (MCLG) which are non-enforceable health goals for public drinking water systems. Non-zero MCLG are relevant and appropriate.	MCL and non-zero MCLG will be used during the development of performance standards for ground-water.

TABLE 3-11 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Ground-Water Monitoring (State)	Rules and Regulations for Ground Water Quality (12-100-006)	Applicable	Establishes ground-water quality standards and/or requirements.	Will be used during the development of performance standards for ground-water.
	Water Pollution Control (RIGL 46-12 et seq) and Water Quality Standards and Ambient Water Quality Guidelines	Relevant and Appropriate	Establishes water use classifications and water quality criteria for all waters of the state. Establishes acute and chronic ambient water quality criteria for the protection of aquatic life.	Discharges of ground water from Site 07 to surface water will comply with the substantive portions of these regulations to the extent that they are more stringent than federal standards.
	Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases ("Remediation Regulations") (DEM-DSR-01-93, as amended Aug. 1996)	Applicable	Establishes Upper Concentration Limits (UCL) and methods for determining contaminant remediation criteria for Class GA and GB ground waters.	Substantive standard, to the extent which it is more stringent than federal standards, will be used during the development of performance standards for shallow and deep ground-water.

**TABLE 3-11 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 6
GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING (Continued)**

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Sediment Monitoring (Federal)	Clean Water Act (33 USC 1251-1376; Federal Ambient Water Quality Criteria, 40 CFR 122.44	Relevant and Appropriate	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms.	Shoreline/offshore sediment is within the discharge area for Site 07 ground water. Therefore, if determined to be necessary during the long-term ground-water monitoring program, AWQC, with modification, will be used to develop performance standards for sediment.
Sediment Monitoring (State)	Water Pollution Control (RIGL 46-12 et seq.) and Water Quality Standards and Ambient Water Quality Guidelines	To Be Considered	Establishes water use classifications and water quality criteria for all waters of the state. Establishes acute and chronic ambient water quality criteria for the protection of aquatic life.	Shoreline/offshore sediment is within the discharge area for Site 07 ground water. Therefore, if determined to be necessary during the long-term ground-water monitoring program, Rhode Island ambient water quality guidelines will be considered for the development of performance standards for sediment.
Discharge (Federal)	Clean Water Act (40 CFR 122-125): National Pollutant Discharge Elimination System (NPDES) Permit Requirements	Applicable	Permits contain applicable effluent standards (i.e., technology-based and/or water quality based), monitoring requirements, and standards and special conditions for discharge.	Discharges of treated ground-water to surface waters will meet these standards.

TABLE 3-11 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Discharge (State)	Rhode Island Water Pollution Control Act			
	Water Quality Regulations for Water Pollution Control (RIGL 46-12 et seq.): Water Quality Standards	Applicable	Establishes general requirements and effluent limits for discharges to area waters.	Discharges of treated water to surface water will meet these requirements.
	Regulations for the Rhode Island Pollutant Discharge Elimination System (no citation number - promulgated June 1984, amended Feb. 96)	Applicable	Permits contain applicable effluent standards (i.e., technology-based and/or water quality-based), monitoring requirements, and standards and special conditions for discharge.	Discharges of treated water to surface water will meet these requirements.
Onsite Treatment (Federal)	RCRA (40 CFR 262) Generator Requirements for Manifesting Waste for Offsite Disposal	Applicable	Standards for manifesting, marking, and recording hazardous waste shipments for offsite treatment/ disposal.	If treatment system by-products require offsite treatment/disposal, then generator requirements will be followed.
	RCRA (40 CFR 264) Subpart I Use and Management of Containers	Applicable	Outlines use and management standards applicable to owners and operators of all hazardous waste facilities that store containers of hazardous waste.	If treatment system by-products require storage of hazardous waste in containers, then management procedures will comply with these requirements.

TABLE 3-11 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Onsite Treatment/ Disposal (State)	Rhode Island Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.)			
	Hazardous Waste Management Rules and Regulations	Relevant and Appropriate	Rules and regulations for hazardous waste generation, transportation, treatment, storage, and disposal.	If treatment system by-products are determined to be hazardous, then these requirements will be met.
	Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases ("Remediation Regulations") (DEM-DSR-01-93, as amended Aug. 1996)	Applicable	Rules and regulations for the investigation and remediation of hazardous materials. Establishes clean-up standards and Upper Concentration Limits (UCL) for hazardous wastes in soil and ground water.	Remedial systems will be designed and operated in accordance with these requirements. Clean-up standards and UCL will be used for the development of performance standards.
	Rhode Island Refuse Disposal Law (23-18.9) Rules and Regulations for Solid Waste Management Facilities (DEM-0WM-SW01-97)	Relevant and Appropriate	Rules and regulations for solid waste management facilities.	These requirements will be met if the treatment system by-products require management as a solid waste.

TABLE 3-11 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
Venting/ Discharges to Air (Federal)	Clean Air Act (40 CFR 61) National Emissions Standards for Hazardous Pollutants (NESHAPS)	Applicable	Establishes emissions limitations for hazardous air pollutants ans sets forth regulated sources of those pollutants.	Air stripping tower emissions will be treated, as necessary, to meet these regulations.
	RCRA 40 CFR 264.1030 - 264.1036 Subpart AA - Air Emission Standards for Process Vents	Applicable	Establishes standards for air emissions from process vents associated with distillation, fractionation, thin film evaporation, column extraction, or air stream stripping operations that treat RCRA substances and have a total organic concentration of 10 ppm or greater.	Air stripping tower emissions will be treated, as necessary, to meet these regulations.
	EPA Technical Guidance Document: Control of Air Emissions from Superfund Air Strippers at Superfund Ground-Water Sites (OSWER Directive 9355.0.28)	To Be Considered	Guidance regarding the control of air emissions from air strippers used at Superfund sites for ground-water treatment. Distinguishes between attainment and non-attainment areas for ozone.	These guidelines will be considered in the design of the air stripping tower and any associated emission treatment units.
Venting/ Discharges to Air (State)	Rhode Island Clean Air Act (RIGL Title 23 Chapter 23) General Air Quality and Air Emissions Requirements	Applicable	Sets emission limitations for particulates and visible air pollutants.	Air stripping tower emissions will be treated, as necessary, to meet these requirements.

TABLE 3-11 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
	Rhode Island Clean Air Act (RIGL Title 23 Chapter 23) General Air Quality and Air Emissions Requirements			
	Air Pollution Control Regulations, RIDoH, Div. of Air Pollution Control, as amended 5/20/1991			
	- Regulation No.1 - Visible Emissions	Applicable	No air contaminant emissions will be allowed for more than 3 minutes in any one hour which are greater than or equal to 20% opacity.	Air stripping tower emissions will be treated, as necessary, to meet these requirements.
	- Regulation No.5 - Fugitive Dust	Applicable	Requires that reasonable precaution be taken to prevent particulate matter from becoming airborne.	Onsite remedial actions will use good industrial practices to prevent particulate matter from becoming airborne.
	- Regulation No.7 - Emissions Detrimental to Person or Property	Applicable	Prohibits emissions of pollutants which may be injurious to human, plant, or animal life or cause damage to property or which reasonably interferes with the enjoyment of life and property.	All emissions will meet this requirement or gas treatment will be used, as necessary.

TABLE 3-11 ACTION-SPECIFIC ARARs AND TBCs FOR ALTERNATIVE 6 GROUND-WATER EXTRACTION AND *EX-SITU* AIR STRIPPING (Continued)

Process	Requirement	Status	Synopsis	Action to be Taken to Meet ARAR
	- Regulation No.9 - Approval to Construct, Install, Modify, or Operate	Applicable	Establishes guidelines for the construction, installation, modification, or operation of potential air emission units. Establishes permissible emission rates.	Construction, installation, modification, or operation of the air stripper unit will meet these requirements.
	- Regulation No.15 - Control of Organic Solvent Emissions	Applicable	Limits the amount of organic solvents emitted to the atmosphere.	Treatment of the offgas from the air stripping tower will be used, as necessary, to meet these requirements.
	- Regulation No.17 - Odors	Applicable	Prohibits the release of objectionable odors across property lines.	No remedial action or air emissions will emit objectionable odors beyond the facility boundary, as practicable.
	- Regulation No. 22 - Air Toxics	Applicable	Prohibits the emission of specified pollutants at rates which would result in ground level concentrations greater than acceptable ambient levels or acceptable ambient levels with LAER, as set in the regulation.	If air emissions contain regulated substances, then air emissions control equipment will be used, as necessary, to meet these requirements.

TABLE 4-1 Preliminary Estimate of Capital Cost for Alternative 2: Deed Restriction and Long-Term Monitoring

Item	Description	Quantity	Unit Cost ($)	Total Cost ($) [a]
1	**Deed Restriction**	--	Lump Sum	5,000
2	**Long-Term Monitoring** [b] • Initial investigations • Dedicated low-flow sampling equip. • New monitoring wells	 -- -- --	 Lump Sum Lump Sum Lump Sum	 29,000 26,000 9,500
			SUBTOTAL	70,000
3	**Closure Report**		Lump Sum	25,000
4	**Mobilization/Demobilization, Construction Management and Site Services**		10%	7,000
5	**Implementation and Design**		10%	7,000
6	**Contingency**		30%	21,000
			TOTAL CAPITAL COST	130,000

(a) Cost estimates are based upon 1998 dollars. Total costs are rounded up to the nearest $100 (if under $10,000) or up to the nearest $1,000 (if over $10,000).
(b) Monitoring costs are conceptual and are subject to change. The scope of the monitoring program is being developed in a Long-Term Risk Monitoring Plan for Site 07.

TABLE 4-2 Preliminary Estimate of Operation and Maintenance Costs for Alternative 2: Deed Restriction and Long-Term Monitoring

Item	Description	Quantity	Unit Cost ($)	Total Cost[a] ($)
1	**Baseline Monitoring** (Year 1)[b]			
	• Sampling (labor/equip./ODC/DV/IDW)	--	Lump Sum	180,000
	• Lab analyses	--	Lump Sum	10,000
	• Reporting	--	Lump Sum	45,000
2	**Repair and Replacement**	--	Lump Sum	12,000
	BASELINE SUBTOTAL ANNUAL O&M COST			247,000
3	**Post-Baseline Monitoring** (Year 2-30)[b]			
	• Sampling (labor/equip./ODC/DV/IDW)	--	Lump Sum	60,000
	• Lab analyses	--	Lump Sum	4,000
	• Reporting	--	Lump Sum	15,000
4	**Repair and Replacement**	--	Lump Sum	12,000
	POST-BASELINE SUBTOTAL ANNUAL O&M COST			91,000

Total 30-Year Present Worth

Capital Cost =	$130,000
Baseline O&M Cost = $ 247,000 Baseline Present Worth O&M Cost =	$ 236,000
Post-Baseline O&M Cost = $ 91,000 Post-Baseline Present Worth O&M Cost =	$ 1,313,000
	======
TOTAL 30-YEAR PRESENT WORTH =	**$ 1,679,000**
	======

(a.) Cost estimates are based upon 1998 dollars. Total costs are rounded up to the nearest $100 (or up to the nearest $1,000 if greater than $10,000).

(b.) Monitoring costs are conceptual and are subject to change. The scope of the monitoring program is being developed in a Long-Term Risk Monitoring Plan for Site 07.

TABLE 4-3 Preliminary Estimate of Capital Cost for Alternative 3: *In-Situ* Anaerobic Biodegradation

Item	Description	Quantity	Unit Cost ($)	Total Cost [a] ($)
1	**Deed Restriction**	--	Lump Sum	5,000
2	**Treatability Study & Tracer Study**	--	Lump Sum	100,000
3	**Ground-Water Modeling** (for design)	--	Lump Sum	50,000
4	**Long-Term Monitoring** [b]			
	• Initial investigations	--	Lump Sum	29,000
	• Dedicated low-flow sampling equip.	--	Lump Sum	26,000
	• New monitoring wells	--	Lump Sum	9,500
5	**Injection Well Installation**			
	• Number of wells in Shallow	2 wells	5,000/well	10,000
	• Number of wells in Deep	6 wells	5,000/well	30,000
6	**Materials**			
	• Substrate [c]	105,000 lbs	0.90/lb	95,000
	• Nutrient	105,000 lbs	0.50/lb	53,000
	• Substrate tank	2 tanks	40,000/tank	80,000
	• Pump	8 pumps	3,200/pump	26,000
	• Tubing (from tank to substrate injection wells)	2,000 LF	0.27/LF	600
7	**System Installation** (building, electrical, etc.)	--	Lump Sum	100,000
			SUBTOTAL	615,000
8	**License Fee** (depending on type of system selected, this may be a proprietary technology)		Lump Sum	50,000
9	**Mobilization/Demobilization, Construction Management, Permitting, and Site Services**		10%	62,000
10	**Design**		10%	62,000
11	**Contingency**		30%	185,000
12	**Closure Report**		Lump Sum	25,000
			TOTAL CAPITAL COST	1,000,000

(a) Cost estimates are based upon 1998 dollars. Total costs are rounded up to the nearest $100 (or up to the nearest $1,000 if greater than $10,000).

(b) Monitoring costs are conceptual and are subject to change. The scope of the monitoring program is being developed in a Long-Term Risk Monitoring Plan for Site 07.

(c) The substrate-to-COC ratio is assumed to be 50 lb/lb. Lab studies will be required to determine the actual ratio.

TABLE 4-4 Preliminary Estimate of Operation and Maintenance Cost for Alternative 3: *In-Situ* Anaerobic Biodegradation

Item	Description	Quantity	Unit Cost ($)	Total Cost [a] ($)
1	**Baseline and System Performance Monitoring** (Year 1) [d]			
	• Sampling (labor/equip./ODC/DV/IDW)	--	Lump Sum	180,000
	• Lab analyses	--	Lump Sum	10,000
	• Reporting	--	Lump Sum	45,000
	• Biodegradation monitoring	--	Lump Sum	203,000
2	**Repair and Replacement**	--	Lump Sum	30,000
			ANNUAL O&M COST FOR YEAR 1 (b)	468,000

Total 30-Year Present Worth

Capital Cost = $ 1,000,000

Annual O&M Cost = variable, but up to $468,000
30-Year Present Worth O&M Cost = $ 2,619,000 (c.)

=========

TOTAL 30-YEAR PRESENT WORTH = $ 3,619,000

=========

(a.) Cost estimates are based upon 1998 dollars. Total costs are rounded up to the nearest $100 (or up to the nearest $1,000 if greater than $10,000).

(b.) Represents Year 1 only. This cost would change over time in order to account for (1) reduced bioremediation monitoring which will likely occur for a 2 year period after each substrate injection; (2) purchase of additional substrate (reduced amount) if determined to be warranted during 5-year reviews based upon observed data; and (3) altered post-baseline monitoring scope.

(c.) Rather than assuming the most expensive year 1 costs for the entire 30 years, the Present Worth was calculated to account for the likely changes in Annual O&M requirements as outlined in footnote (b).

(d.) Monitoring costs are conceptual and are subject to change. The scope of the monitoring program is being developed in a Long-Term Risk Monitoring Plan for Site 07.

TABLE 4-5 Preliminary Estimate of Capital Costs for Alternative 4: Vacuum-Vaporizer Well

Item	Description	Quantity	Unit Cost ($)	Total Cost [a] ($)
1	**Deed Restriction**	--	Lump Sum	5,000
2	**System for shallow aquifer** • Vacuum-Vaporizer Well system • 5 HP, 208-230 V, 3-phase blower • Moisture knock-out • Weatherproof blower stand • Screens, well head, and operations manual	1 system	70,000/system	70,000
3	**System for deep aquifer** • Vacuum-Vaporizer Well system including 5 HP, 208-230 V • 3-phase blower • Moisture knock-out • Weatherproof blower stand • One 1/3 hp 1-phase pump • Screens, well head, and operations manual	3 systems	87,000/system	261,000
4	**Drilling** • 1 shallow pilot hole • 3 deep pilot hole • 1 boring for shallow system • 3 borings for deep system • 16" Steel casing for treatment wells • Ancillary Services and Materials • Waste Containerization and Disposal	 20 ft 50 ft 20 ft 50 ft 170 ft -- --	 12/ft 12/ft 65/ft 65/ft 133/ft Lump Sum Lump Sum	 300 1,800 1,300 9,800 22,700 6,000 17,000
5	**Pilot Hole** • Slug test and sieve analysis	4 holes	500/hole	2,000
6	**Treatability Study** • Recirculation and tracer study	--	Lump Sum	200,000
7	**Air Filtration System** • Foundation, GAC canisters, instrumentation, and fittings	--	Lump Sum	115,000
8	**System Installation** • Building, electrical, etc.	--	Lump Sum	100,000
9	**Technical support**	--	Lump Sum	27,000
10	**Long-Term Monitoring** [b] • Initial investigations • Dedicated low-flow sampling equip. • New monitoring wells	 -- -- --	 Lump Sum Lump Sum Lump Sum	 29,000 26,000 9,500
			SUBTOTAL	904,000

TABLE 4-5 Preliminary Estimate of Capital Costs for Alternative 4: Vacuum-Vaporizer Well (Continued)

Item	Description	Quantity	Unit Cost ($)	Total Cost [(a)] ($)
11	**Mobilization/Demobilization, Construction Management, Permitting, and Site Services**		10%	91,000
12	**Design**		10%	91,000
13	**Contingency**		30%	272,000
14	**Closure Report**		Lump Sum	25,000
			TOTAL CAPITAL COST	1,383,000

(a) Cost estimates are based upon 1998 dollars. Total costs are rounded up to the nearest $100 (or up to the nearest $1,000 if greater than $10,000).

(b) Monitoring costs are conceptual and are subject to change. The scope of the monitoring program is being developed in a Long-Term Risk Monitoring Plan for Site 07.

TABLE 4-6 Preliminary Estimate of Operational and Maintenance Costs for Alternative 4: Vacuum-Vaporizer Wells

Item	Description	Quantity	Unit Cost ($)	Total Cost (a) ($)
1	**Baseline and System Performance Monitoring** (Year 1)[b]			
	• Sampling events (labor/equip./ODC/DV/IDW)	--	Lump Sum	210,000
	• Lab analyses	--	Lump Sum	12,000
	• Reporting	--	Lump Sum	60,000
2	**Repair and Replacement**	--	Lump Sum	100,000
3	**Effluent Air Sampling** • Weekly air sampling (incl. TCL VOC and QA/QC analysis, labor/equip.)	120 samples/yr	300/sample	36,000
4	**Screen Maintenance** • Includes cleaning/replacement	1/yr	Lump Sum	7,000
5	**Vapor Phase GAC system** • Includes waste characterization, transportation, and GAC treatment	--	Lump Sum	43,000
			BASELINE SUBTOTAL ANNUAL O&M COST	468,000
6	**Post-Baseline and System Performance Monitoring** (Year 2-30)[b]			
	• sampling events (labor/equip./ODC/DV/IDW)	--	Lump Sum	70,000
	• lab analyses	--	Lump Sum	4,000
	• reporting	--	Lump Sum	20,000
7	**as items 2-5 above**	--	Lump Sum	186,000
			POST-BASELINE SUBTOTAL ANNUAL O&M COST	280,000

Total 30-Year Present Worth

Capital Cost = $ 1,383,000

Baseline O&M Cost =$ 468,000
Baseline Present Worth O&M Cost (5% rate) = $ 446,000

Post-Baseline O&M Cost = $ 280,000
Post-Baseline Present Worth O&M Cost (5% rate) = $ 4,038,000

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TOTAL 30-YEAR PRESENT WORTH = $ 5,867,000

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(a.) Cost estimates are based upon 1998 dollars. Total costs are rounded up to the nearest $100 (or up to the nearest $1,000 if greater than $10,000).

(b.) Monitoring costs are conceptual and are subject to change. The scope of the monitoring program is being developed in a Long-Term Risk Monitoring Plan for Site 07.

TABLE 4-7 Preliminary Estimate of Capital Costs for Alternative 5: *In-Situ* Permeable Reaction Wall

Item	Description	Quantity	Unit Cost ($)	Total Cost [a] ($)
1	**Deed Restriction**	1	Lump Sum	5,000
2	**Treatability Study**	1	Lump Sum	100,000
3	**Vertical Barriers** • Sheet Pile Wall (incl. installation) ([800+ 900] x 50 ft^2)	85,000 ft^2	20/ft^2	1,700,000
4	**Reaction wall** (200 ft x 35 ft x 4 ft) • Iron • Wall Construction	 28,000 ft^3 (0.09 ton/ft^3) 200 ft	 400/ton Lump Sum	 1,008,000 750,000
5	**Licensing fee, Engineering, H&S** (15% of items 3 + 4)	--	Lump Sum	519,000
6	**Performance Monitoring** • Install new shallow monitoring wells • Install new deep monitoring wells • Install piezometers	 3 wells 4 wells 8 piezometers	 1200/well 3200/well 1000/each	 3,600 13,000 8,000
7	**Long-Term Monitoring** [b] • Initial investigations • Dedicated low-flow sampling equip. • New monitoring wells	 -- -- --	 Lump Sum Lump Sum Lump Sum	 29,000 26,000 9,500
			SUBTOTAL	4,172,000
8	**Mobilization/Demobilization, Construction Management, and Site Services**		10%	418,000
9	**Design**		10%	418,000
10	**Contingency**		30%	1,252,000
11	**Closure report**		Lump Sum	25,000
			TOTAL CAPITAL COST	6,285,000

(a) Cost estimates are based upon 1998 dollars. Total costs are rounded up to the nearest $100 (or up to the nearest $1,000 if greater than $10,000).

(b) Monitoring costs are conceptual and are subject to change. The scope of the monitoring program is being developed in a Long-Term Risk Monitoring Plan for Site 07.

TABLE 4-8 Preliminary Estimate of Operation and Maintenance Costs for Alternative 5: *In-Situ* Permeable Reaction Wall

Item	Description	Quantity	Unit Cost ($)	Total Cost [a] ($)
1	**Baseline and System Performance Monitoring** (Year 1) [b]			
	• Sampling (labor/equip./ODC/DV/IDW)	--	Lump Sum	210,000
	• Lab analyses	--	Lump Sum	12,000
	• Reporting	--	Lump Sum	60,000
2	**Repair and Replacement**			
	• Reaction wall maintenance	(c)	Lump Sum	60,000
	• System maintenance	--	Lump Sum	15,000
	BASELINE SUBTOTAL ANNUAL O&M COST			357,000
3	**Post-Baseline Monitoring** (Year 2-30) [b]			
	• Sampling (labor/equip./ODC/DV/IDW)	--	Lump Sum	70,000
	• Lab analyses	--	Lump Sum	4,000
	• Reporting	--	Lump Sum	20,000
4	**Repair and Replacement**			
	• Reaction wall maintenance	(c)	Lump Sum	60,000
	• System maintenance	--	Lump Sum	15,000
	POST-BASELINE SUBTOTAL ANNUAL O&M COST			169,000

Total 30-Year Present Worth

Capital Cost =	$6,285,000
Baseline O&M Cost =$ 357,000	
Baseline Present Worth O&M Cost (5% rate) =	$ 340,000
Post-Baseline O&M Cost =$ 169,000	
Post-Baseline Present Worth O&M Cost (5% rate) =	$ 2,437,000
	======
TOTAL 30-YEAR PRESENT WORTH =	**$ 9,062,000**
	======

(a.) Cost estimates are based upon 1998 dollars. Total costs are rounded up to the nearest $100 (or up to the nearest $1,000 if greater than $10,000).

(b.) Monitoring costs are conceptual and are subject to change. The scope of the monitoring program is being developed in a Long-Term Risk Monitoring Plan for Site 07.

(c.) Based on a replacement of the reactive wall once every five years at a cost of $300,000 per replacement (for purposes of cost analysis, this was calculated as $60,000 per year).

TABLE 5-1 COMPARISON OF FEASIBLE REMEDIAL ALTERNATIVES FOR SITE 07

Alternative	Description	Type of Action	Subject to Land Disposal Regulations	Requires Offsite Transport/ Disposal	Costs [(a)]		
					Capital Costs ($)	Annual O&M Costs ($)	Total 30-Yr Present Worth ($)
1	No Action	No Action	No	No	None	Nominal	Nominal
2	Deed Restriction and Long-Term Monitoring	Institutional Controls	No	No	130,000	247,000	1,679,000
3	*In-Situ* Anaerobic Bioremediation	*In-Situ* Ground-Water Treatment	No	No	1,000,000	468,000	3,619,000
4	Vacuum-Vaporizer Wells	*In-Situ* Ground-Water Treatment	No	Yes	1,383,000	468,000	5,867,000
5	*In-Situ* Permeable Reaction Wall	*In-Situ* Ground-Water Treatment	No	No	6,285,000	357,000	9,062,000

(a) Costs are based on 1998 dollars and are rounded up to the nearest $1,000.

TABLE 5-2 SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES FOR SITE 07

Criteria	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Deed Restriction and Long-Term Monitoring	ALTERNATIVE 3 *In-Situ* Anaerobic Bioremediation	ALTERNATIVE 4 Vacuum-Vaporizer Wells	ALTERNATIVE 5 *In-Situ* Permeable Reaction Wall
OVERALL PROTECTIVENESS - HUMAN HEALTH					
Ingestion/use of deep ground water	Would not address risk.	Deed restriction would address risk.	Deed restriction would address risk. Would treat deep ground-water source area.	Deed restriction would address risk. Would treat deep ground-water source area.	Deed restriction would address risk. Would treat deep ground water exiting Site 07.
Ingestion/use of bedrock ground water	Would not address risk.	Deed restriction would address risk.	Deed restriction would address risk. May have limited effectiveness for treating bedrock ground water.	Deed restriction would address risk. May have limited effectiveness for treating bedrock ground water.	Deed restriction would address risk.
OVERALL PROTECTIVENESS - ENVIRONMENT					
Potential Offshore Receptors	Not applicable; no risks identified for potential offshore receptors.	Not applicable; no risks identified for potential offshore receptors.	Not applicable; no risks identified for potential offshore receptors.	Not applicable; no risks identified for potential offshore receptors.	Not applicable; no risks identified for potential offshore receptors.
Potential Onsite Receptors	Not applicable; no risks identified for potential onsite receptors.	Not applicable; no risks identified for potential onsite receptors.	Not applicable; no risks identified for potential onsite receptors.	Not applicable; no risks identified for potential onsite receptors.	Not applicable; no risks identified for potential onsite receptors.

TABLE 5-2 SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES FOR SITE 07 (Continued)

Criteria	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Deed Restriction and Long-Term Monitoring	ALTERNATIVE 3 *In-Situ* Anaerobic Bioremediation	ALTERNATIVE 4 Vacuum-Vaporizer Wells	ALTERNATIVE 5 *In-Situ* Permeable Reaction Wall
COMPLIANCE WITH ARARs					
Chemical-specific	Not applicable.	Not applicable.	Not applicable.	Not applicable.	Not applicable.
Location-specific	No impacts to wetlands, marshes, or potential endangered species at the site.	No impacts to wetlands, marshes, or potential endangered species at the site.	Minimal impact to wetlands, marshes, or potential endangered species at the site during well installation.	Low impact to wetlands, marshes, or potential endangered species at the site during well installation and system operation.	Some impact to wetlands, marshes, or potential endangered species at the site during trenching and sheetpile installation.
Action-specific	Not applicable.	Will comply with monitoring requirements.	Will comply with system operation and monitoring requirements.	Will comply with system operation and monitoring requirements.	Will comply with system operation and monitoring requirements.

TABLE 5-2 SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES FOR SITE 07 (Continued)

Criteria	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Deed Restriction and Long-Term Monitoring	ALTERNATIVE 3 *In-Situ* Anaerobic Bioremediation	ALTERNATIVE 4 Vacuum-Vaporizer Wells	ALTERNATIVE 5 *In-Situ* Permeable Reaction Wall
LONG-TERM EFFECTIVENESS AND PERMANENCE					
Magnitude of Residual Risk	Does not address long-term risk.	Deed restriction to address residual risk.	Deed restriction to address residual risk.	Deed restriction to address residual risk.	Deed restriction to address residual risk.
Adequacy and Reliability of Controls	Not applicable.	Deed restriction will be reliable and easy to control.	Deed restriction will be reliable and easy to control. Standard equipment controls but adequacy and reliability of this innovative technology can be difficult to predict. Anaerobic bioremediation can be difficult to start and maintain. Monitoring will facilitate the long-term evaluation.	Deed restriction will be reliable and easy to control. The long-term adequacy and reliability of this innovative technology can be difficult to predict. Monitoring will facilitate the long-term evaluation.	Deed restriction will be reliable and easy to control. The long-term adequacy and reliability of this innovative technology can be difficult to predict. The reactive wall will require periodic upkeep to continue effectiveness. Monitoring will facilitate the long-term evaluation.

TABLE 5-2 SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES FOR SITE 07 (Continued)

Criteria	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Deed Restriction and Long-Term Monitoring	ALTERNATIVE 3 *In-Situ* Anaerobic Bioremediation	ALTERNATIVE 4 Vacuum-Vaporizer Wells	ALTERNATIVE 5 *In-Situ* Permeable Reaction Wall
REDUCTION OF TOXICITY, MOBILITY, AND VOLUME THROUGH TREATMENT					
Reduction of toxicity, mobility, and volume through treatment.	No treatment included.	No treatment included. Risks associated with the toxicity, mobility, and volume of COC would be addressed through deed restriction.	Toxicity and volume of organic COC reduced in some areas through biodegradation except for possible formation of VC. Unlikely to be effective for COC in bedrock ground water; however, risks associated with the toxicity, mobility, and volume of COC would be addressed through a deed restriction.	Toxicity, mobility, and volume reduced through removal of COC from shallow and deep ground water in some areas. COC transferred to GAC and/or air. Unlikely to be effective for COC in bedrock ground water; however, risks associated with the toxicity, mobility, and volume of COC would be addressed through a deed restriction.	Mobility of COC in shallow/deep ground water restricted to east/west by sheetpile walls. Toxicity and volume of COC reduced in shallow/ deep ground water exiting the site. Will not be effective for COC in bedrock ground water; however, risks associated with the toxicity, mobility, and volume of COC would be addressed through a deed restriction.

TABLE 5-2 SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES FOR SITE 07 (Continued)

Criteria	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Deed Restriction and Long-Term Monitoring	ALTERNATIVE 3 *In-Situ* Anaerobic Bioremediation	ALTERNATIVE 4 Vacuum-Vaporizer Wells	ALTERNATIVE 5 *In-Situ* Permeable Reaction Wall
Hazardous material destroyed or treated	No treatment included.	No treatment included.	Organic COC in onsite shallow and deep ground water degraded through anaerobic biodegradation in some areas. Unlikely to be effective for COC in bedrock ground water.	Volatile COC in shallow and deep ground water will not be destroyed, rather, they will be removed from ground water in some areas and transferred to GAC and/or air. Unlikely to be effective for COC in bedrock ground water.	COC in source areas will not be treated. Organic COC in shallow and deep ground water exiting the site will be chemically degraded through the reactive wall. Unlikely to be effective for COC in bedrock ground water.
Type and Quantity of Residuals Remaining After Treatment	No treatment specified.	No treatment specified; however risks associated with residuals would be addressed through a deed restriction.	Will treat portions of shallow and deep plume. Dissolved-phase chlorinated COC degraded; complete degradation results in non-toxic compounds. Will not treat arsenic in ground water and may not address potential residual DNAPL in soil and COC in bedrock; however risks associated with residuals would be addressed through a deed restriction.	Source area treatment only. Dissolved-phase COC removed from shallow and deep ground water. Will not treat arsenic in ground water and may not address potential residual DNAPL in soil and COC in bedrock; however risks associated with residuals would be addressed through a deed restriction.	No onsite or bedrock treatment specified; however risks associated with residuals would be addressed through a deed restriction. Chlorinated COC migrating off Site 07 degraded into non-toxic compounds. Will not treat arsenic, benzene, and 1,2-DCA in ground water exiting the site.

TABLE 5-2 SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES FOR SITE 07 (Continued)

Criteria	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Deed Restriction and Long-Term Monitoring	ALTERNATIVE 3 *In-Situ* Anaerobic Bioremediation	ALTERNATIVE 4 Vacuum-Vaporizer Wells	ALTERNATIVE 5 *In-Situ* Permeable Reaction Wall
Statutory Preference for Treatment	Does not meet.	Does not meet.	Meets for shallow and deep ground water. Does not meet for bedrock ground water.	Meets for shallow and deep ground water. Does not meet for bedrock ground water.	Does not meet for onsite (source area) or bedrock ground water. Meets for shallow and deep ground water exiting the site.
SHORT-TERM EFFECTIVENESS					
Protection of site workers (construction, operation, sampling crews)	No risks to site workers.	Safety controls will address the nominal risks to site workers during well installation and monitoring.	Safety controls will address the nominal risks to site workers during well installation and monitoring.	Safety controls will address the nominal risks to site workers during well installation and monitoring. Additional potential risks from venting or *ex-situ* treatment of extracted COC.	Safety controls will address the nominal risks to site workers during well installation and monitoring. Presents the greatest potential risks to site workers during trenching operations.
Protection of community	No new risks to the community.	No new risks to the community.	No new risks to the community.	GAC will be used, as necessary, to treat system offgas.	No new risks to the community. Will generate temporary high levels of noise during installation of sheetpile walls.

TABLE 5-2 SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES FOR SITE 07 (Continued)

Criteria	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Deed Restriction and Long-Term Monitoring	ALTERNATIVE 3 *In-Situ* Anaerobic Bioremediation	ALTERNATIVE 4 Vacuum-Vaporizer Wells	ALTERNATIVE 5 *In-Situ* Permeable Reaction Wall
Time to Achieve Remedial Goals	Remedial goals would not be met because risks would not be addressed.	Deed restrictions would immediately address site risks.	Deed restrictions would immediately address site risks. Time to remediate shallow and deep ground water would be determined based upon a treatability study.	Deed restrictions would immediately address site risks. Time to remediate shallow and deep ground water would be determined based upon a treatability study.	Deed restrictions would immediately address site risks. No treatment of ground-water source areas.
IMPLEMENTABILITY					
Ability to construct and operate	Not applicable.	Not applicable.	Innovative technology requiring treatability study. Difficult to implement due to mass transfer limitations; however, standard construction procedures would be used.	Innovative technology requiring treatability study. Innovative well design used. Standard construction procedures used.	Innovative technology requiring treatability study. Standard construction procedures used.
Ease of conducting other actions, if needed	Other actions would be readily implementable, if needed.	Other actions would be readily implementable, if needed.	Other remedial actions, if needed, may be implemented provided the injection system and anaerobic conditions are not disturbed.	Other remedial actions, if needed, may be implemented provided that the wells and *ex-situ* treatment system are not disturbed.	Other remedial actions, if needed, would be readily implementable within the plume area because the remediation system will be installed around the perimeter of the plume.

TABLE 5-2 SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES FOR SITE 07 (Continued)

Criteria	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Deed Restriction and Long-Term Monitoring	ALTERNATIVE 3 *In-Situ* Anaerobic Bioremediation	ALTERNATIVE 4 Vacuum-Vaporizer Wells	ALTERNATIVE 5 *In-Situ* Permeable Reaction Wall
Ability to monitor effectiveness	Although no monitoring is specified, the existing monitoring well network onsite can be used or modified if needed.	Existing monitoring well network can be used or modified.	Existing monitoring well network can be used or modified.	Existing monitoring well network can be used or modified.	Existing monitoring well network can be used or modified. Additional monitoring wells to be installed downgradient of the reactive wall. Additional shallow and deep piezometers to be installed along side-gradient sheet pile walls.
Ability to obtain approvals and coordinate with other agencies	Not likely to receive approval because risks would not be addressed.	May receive regulatory approval because risks would be effectively addressed and ground-water treatment may not be warranted (or practicable for bedrock).	Remediation system will require coordination with RIDEM for operation of injection wells.	Remediation system may require coordination with RIDEM to ensure that system offgas meets the substantive requirements for air pollution control.	Installation of the remediation system will require coordination with the RIDEM, the U.S. Fish and Wildlife Service, and the CRMC because of disturbances to the shoreline and shoreline habitat.

TABLE 5-2 SUMMARY OF COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES FOR SITE 07 (Continued)

Criteria	ALTERNATIVE 1 No Action	ALTERNATIVE 2 Deed Restriction and Long-Term Monitoring	ALTERNATIVE 3 *In-Situ* Anaerobic Bioremediation	ALTERNATIVE 4 Vacuum-Vaporizer Wells	ALTERNATIVE 5 *In-Situ* Permeable Reaction Wall
Availability of Materials and Services	Not applicable.	The required equipment and services for monitoring are readily available.	*In-Situ* Anaerobic Biodegradation is an innovative technology and the required services for system testing and operation are limited. The required equipment and services for construction of an injection system are readily available.	Vacuum-Vaporizer Wells are an innovative technology and vendors are limited. The required equipment and services for the *ex-situ* treatment system are readily available.	An *in-situ* permeable reaction wall is an innovative technology and the vendors are limited. The required services and equipment for sheetpile walls are readily available.
COST					
Capital Cost	None	$130,000	$1,000,000	$1,383,000	$6,285,000
Annual O&M Cost	Nominal (5-year reviews)	$247,000	$468,000	$468,000	$357,000
Total 30-Year Present Worth Cost	Nominal	$1,679,000	$3,619,000	$5,867,000	$9,062,000

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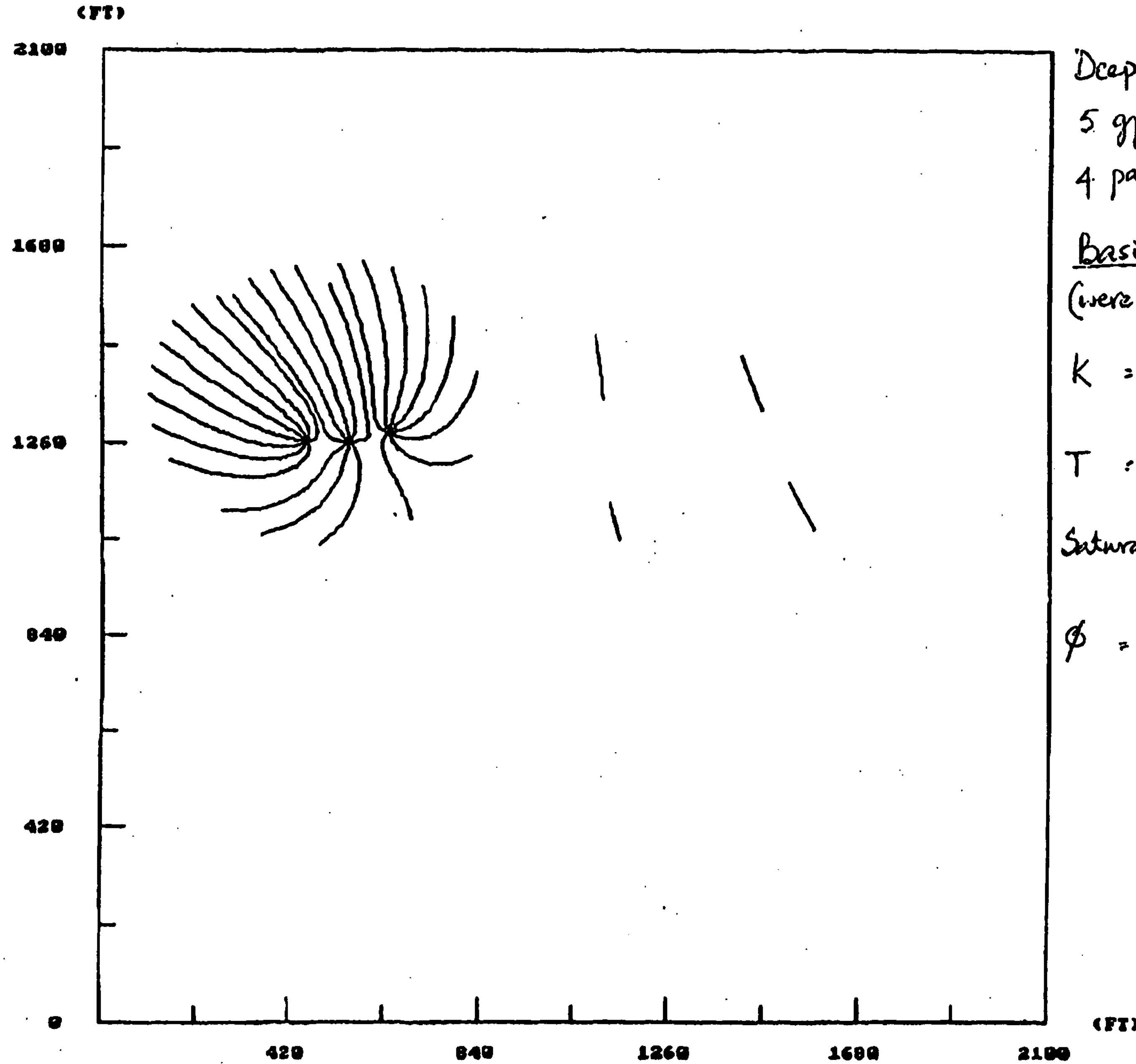
Appendix A

WHPA Model Results for Potential Ground-Water Extraction Scenarios under Alternative 6



Deep Extraction Wells

5 gpm

4 particle tracking points

<u>Basic model input param</u>

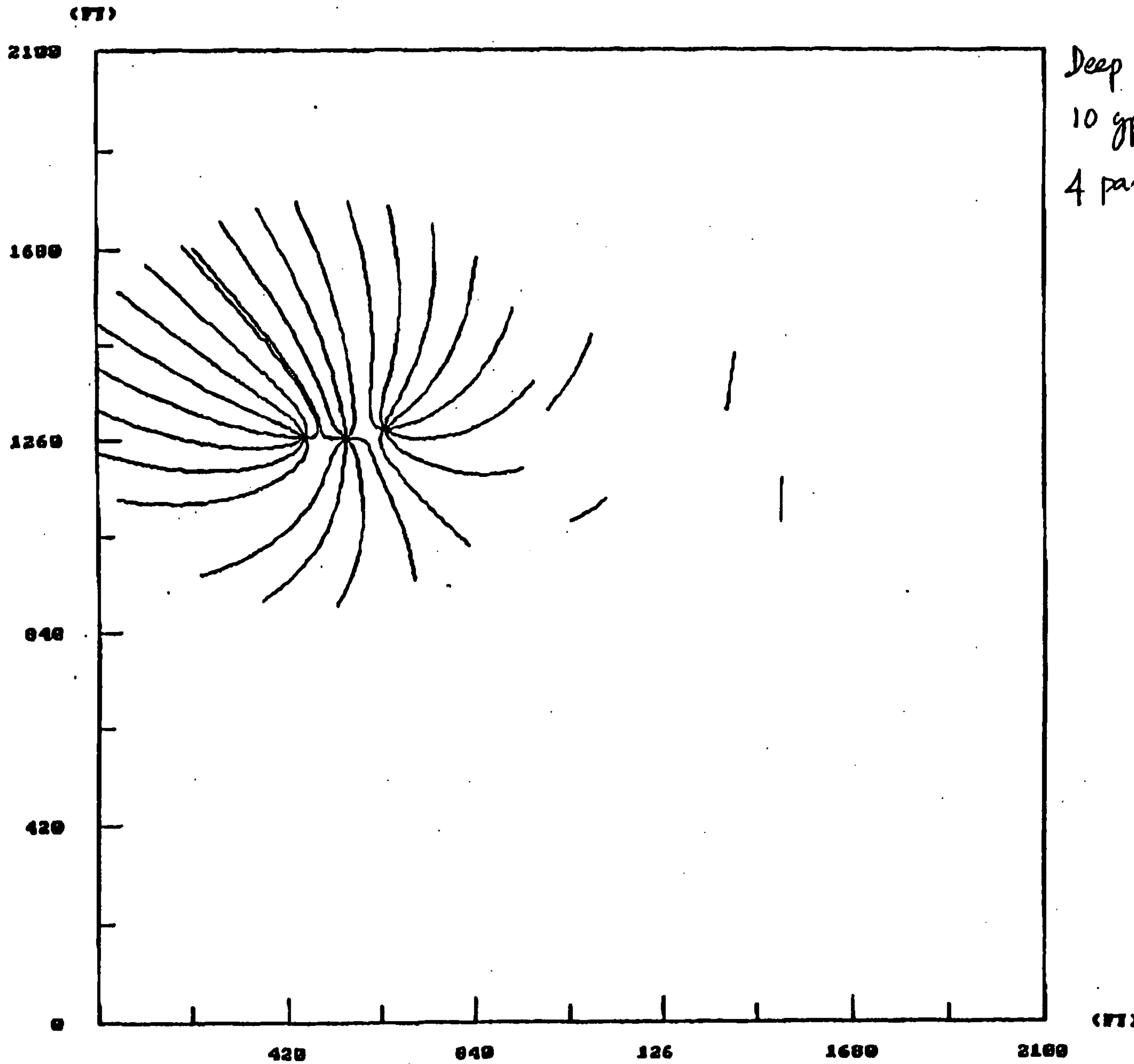
(were not changed for each scen

K = 30 ft/day

T : 150 ft²/day

Saturated thickness, b = 5.0 f

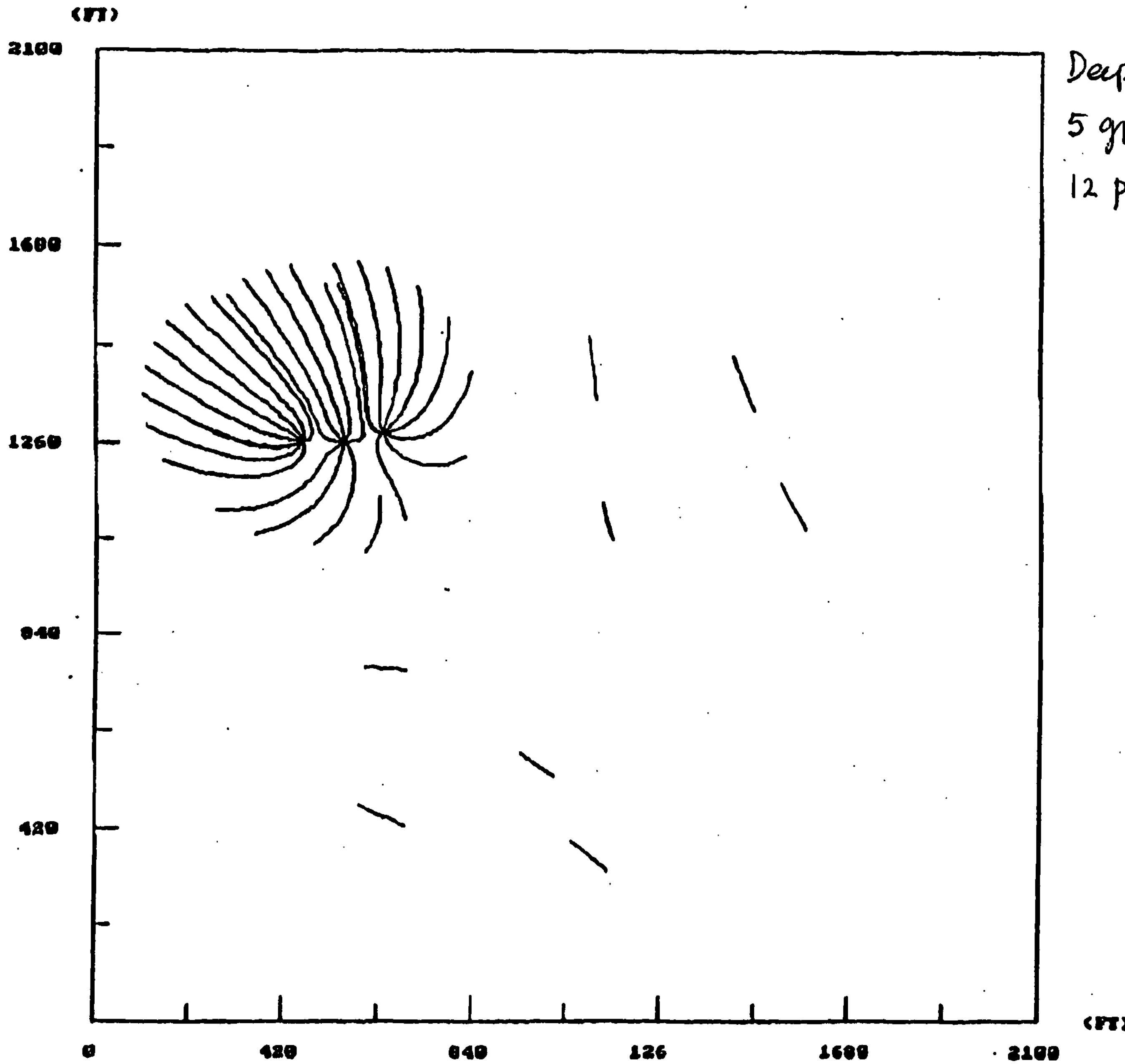
ϕ = 0.30



Deep Extraction Wells

10 gpm

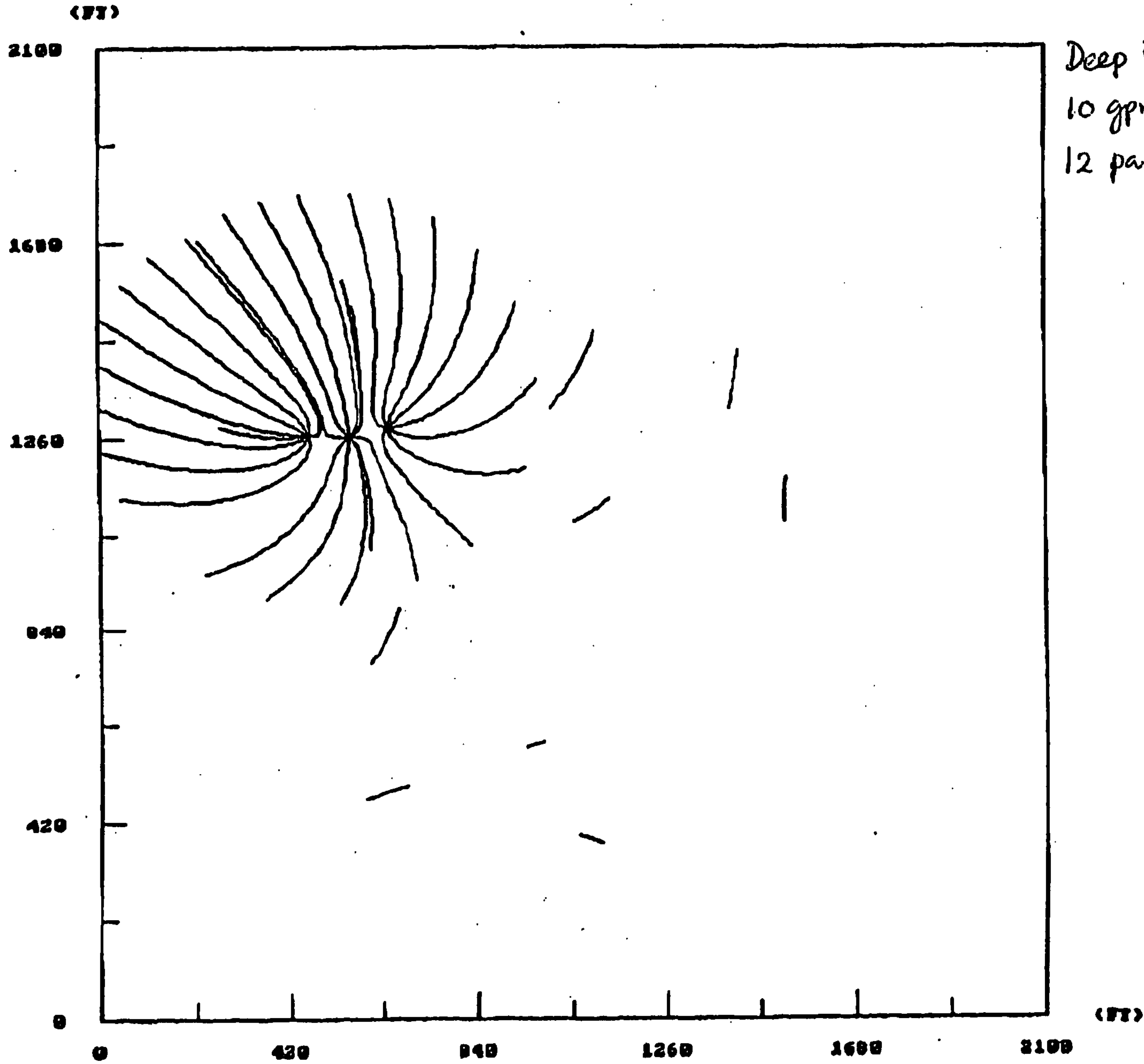
4 particle tracking points



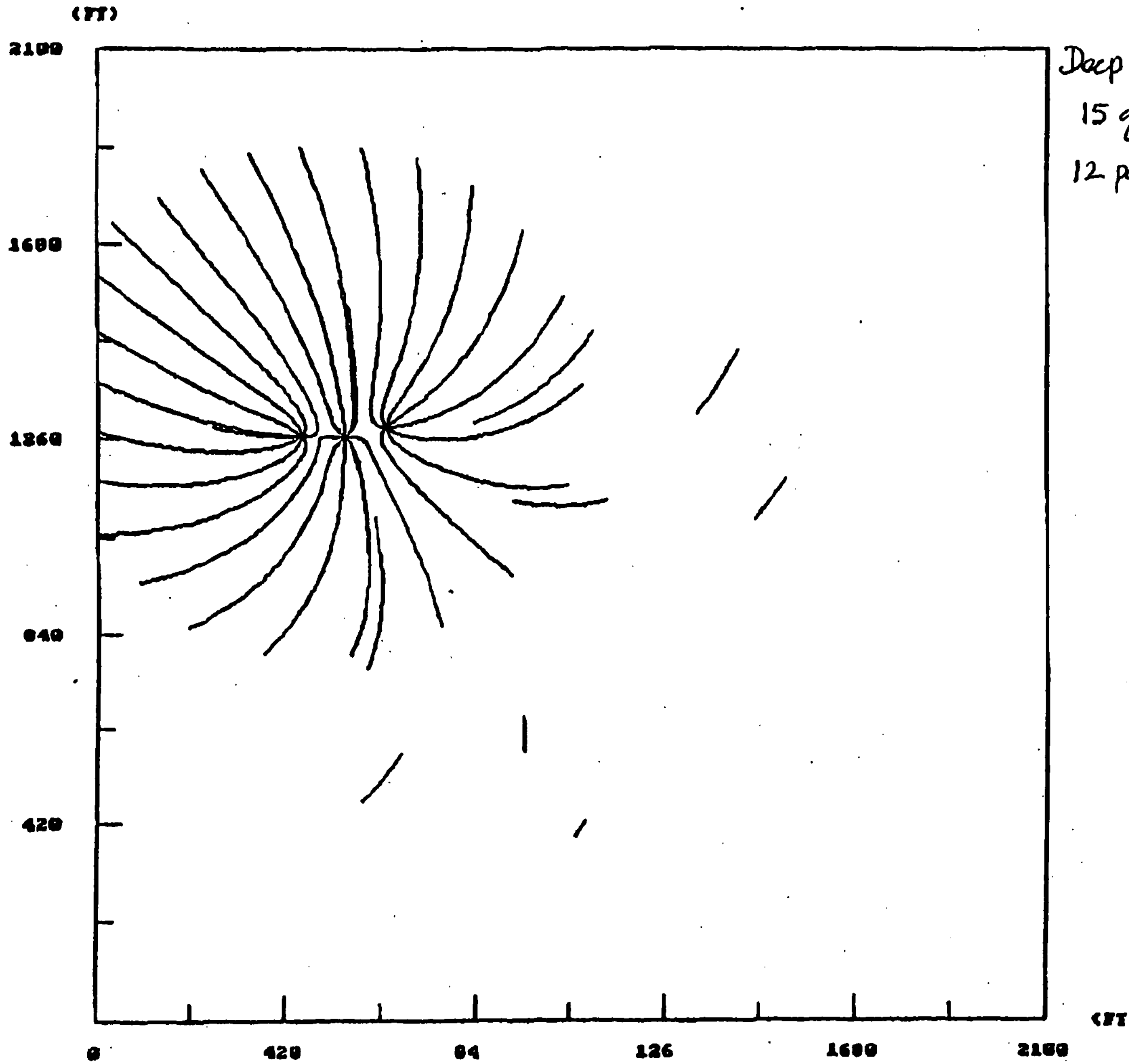
Deep Extraction Wells

5 gpm

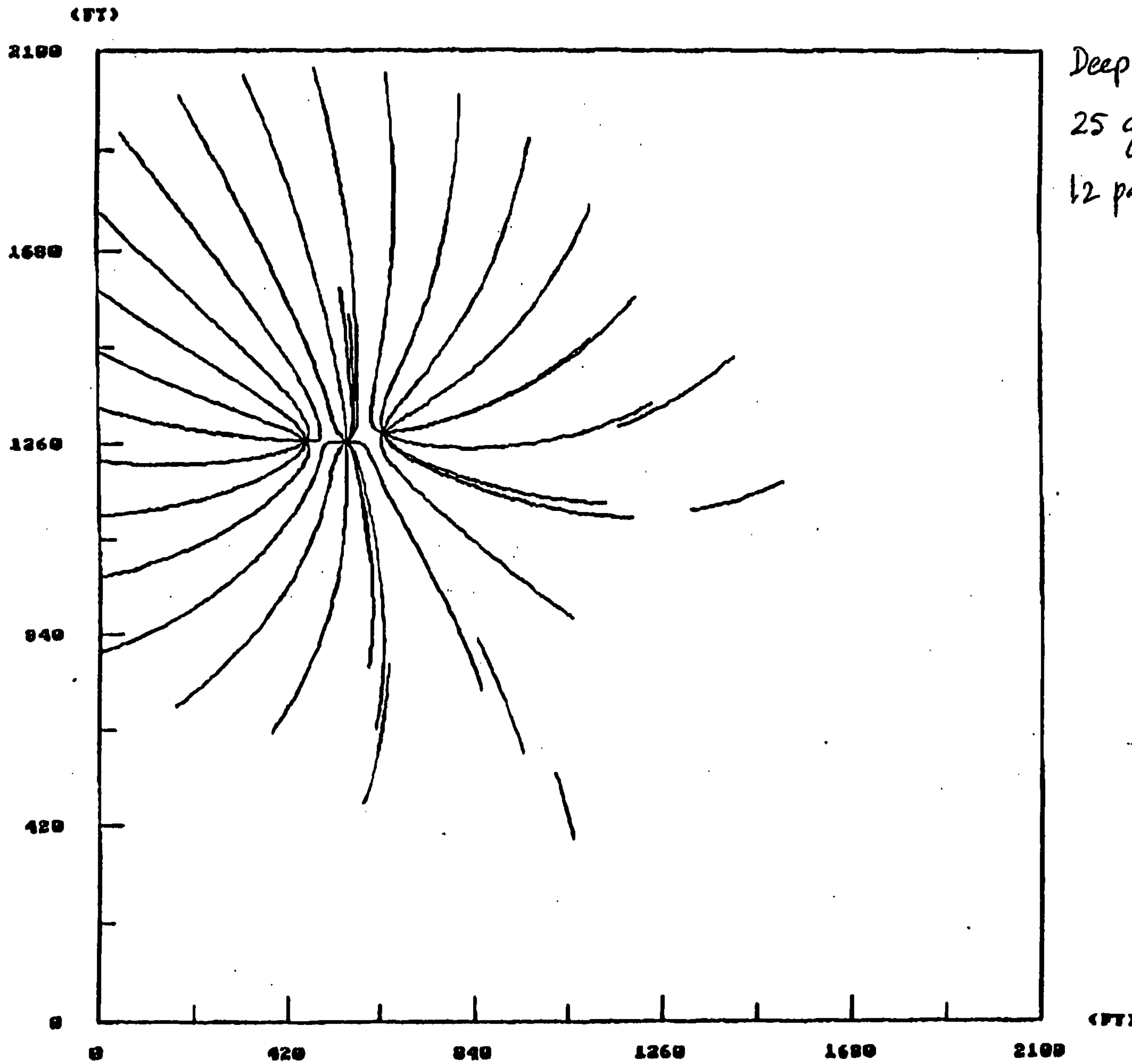
12 particle tracking points



Deep Extraction Wells
10 gpm
12 particle tracking points



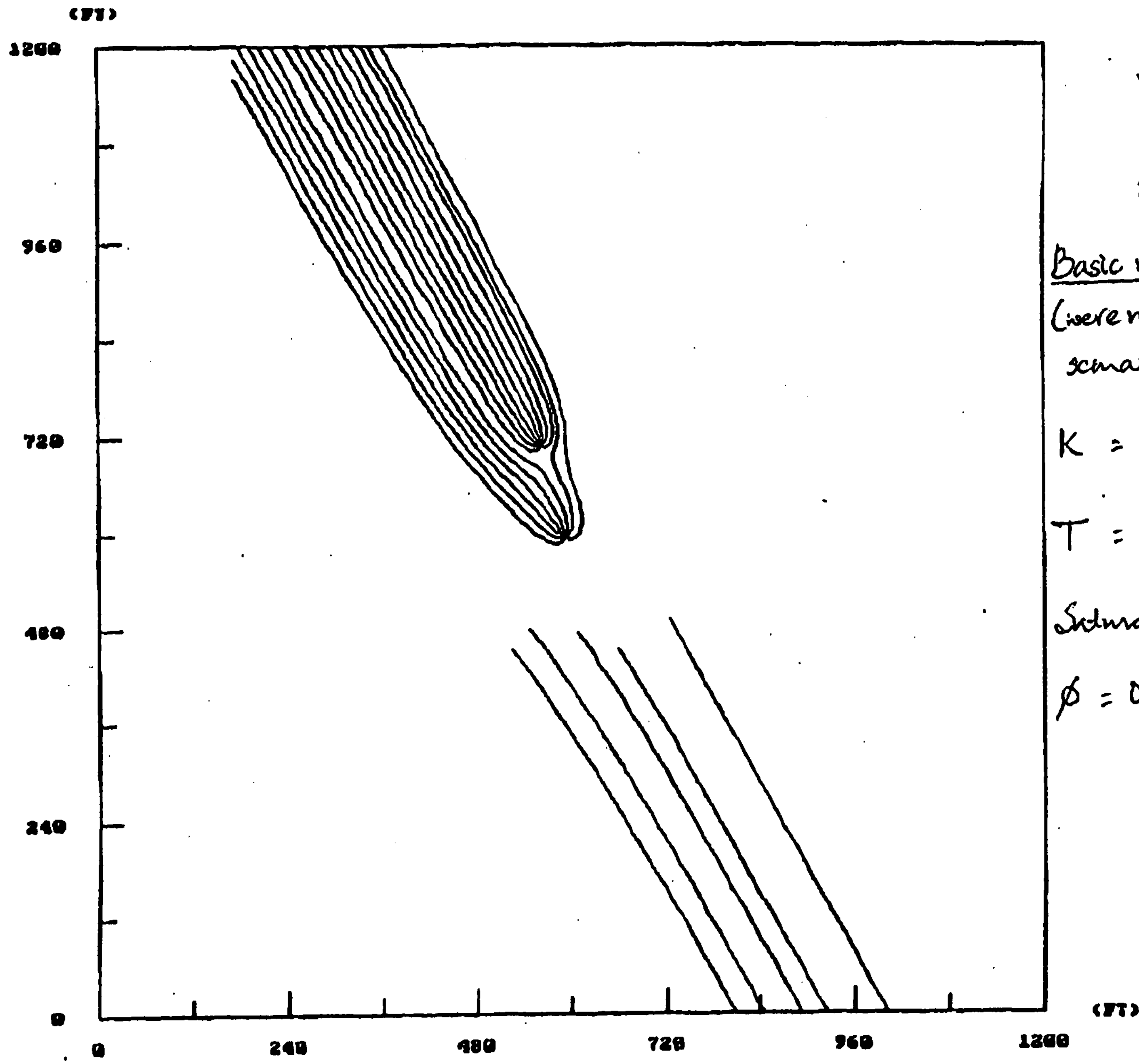
Deep Extraction Wells
15 gpm
12 particle tracking points



Deep Extraction Wells

25 gpm

12 particle tracking points.



Shallow Extraction We

10 gpm

5 particle tracking po

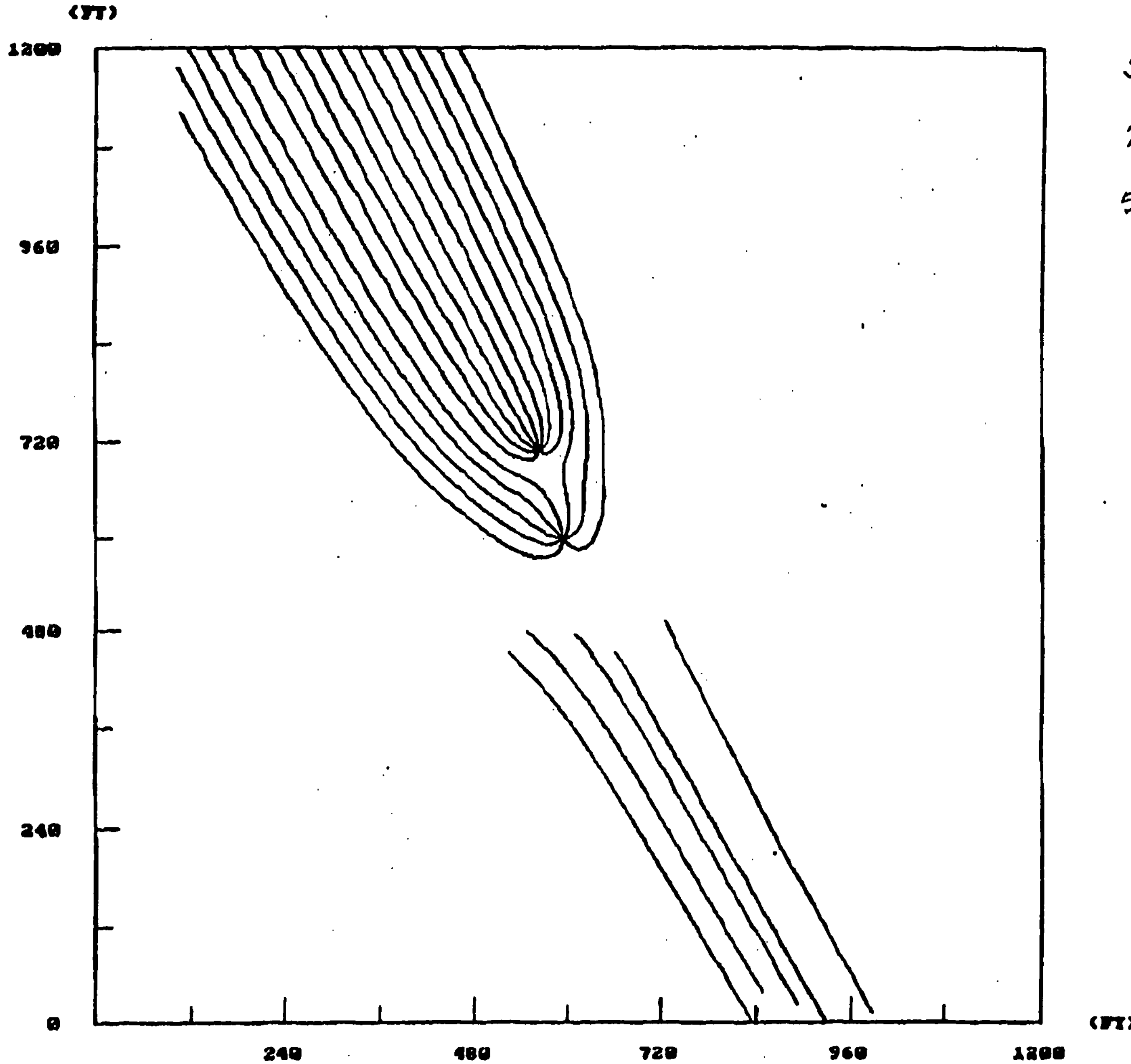
<u>Basic model input parameter</u>
(were not changed for each scenario)

K = 133.3 ft/day

T = 2332.8 ft²/day

Saturated thickness, b = 17.5

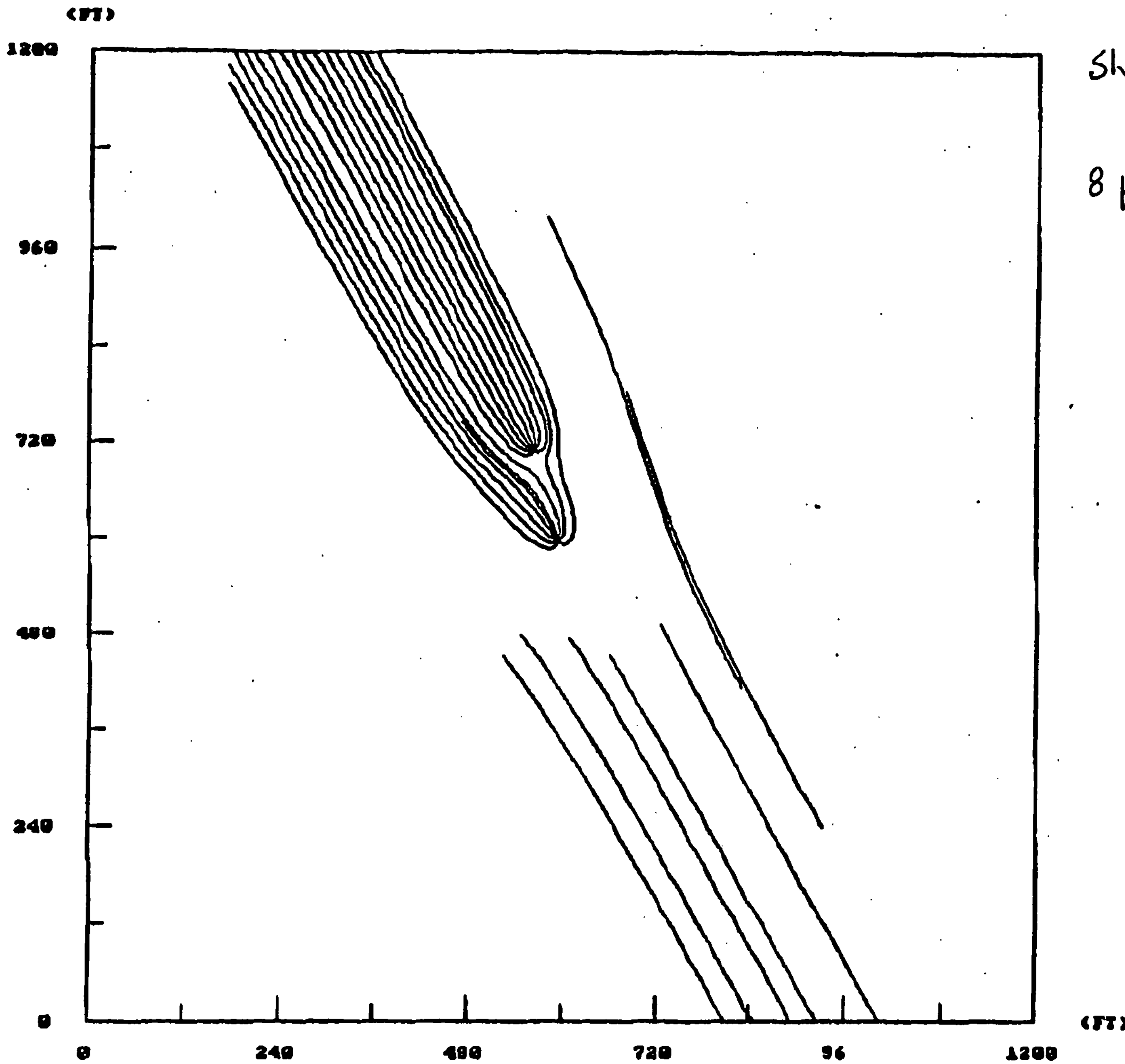
ϕ = 0.30



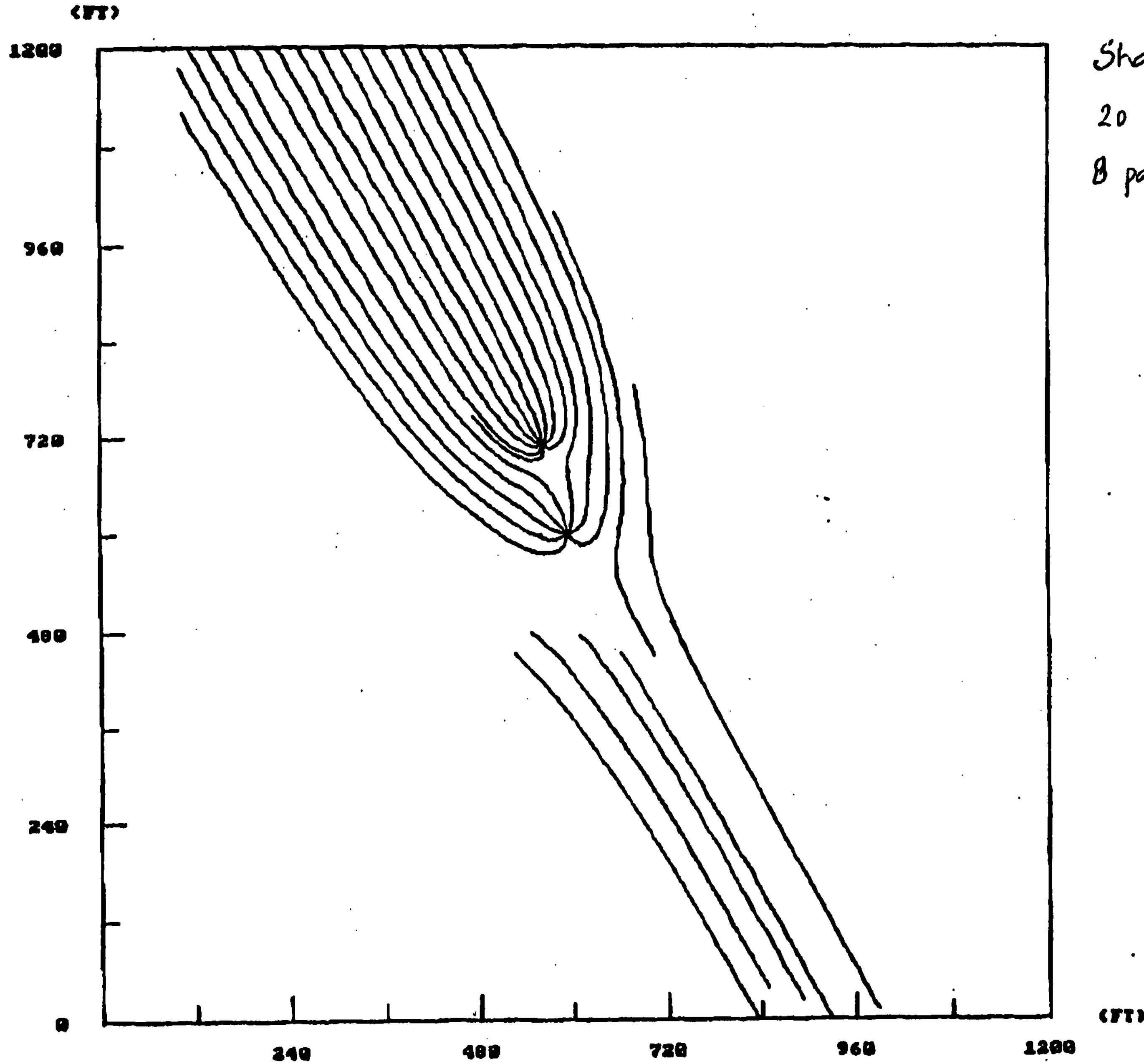
Shallow Extraction Wel

20 gpm

5 particle tracking point



Shallow Extraction Well
10 gpm
8 particle tracking points



Shallow Extraction Wells

20 gpm

8 particle tracking points

Appendix B

Cost Estimates for Alternative 6

TABLE B-1 Preliminary Estimate of Capital Costs For Alternative 6: Ground-Water Extraction with Air Stripping

Item	Description	Quantity	Unit Cost ($)	Total Cost [a] ($)
1	**Deed Restrictions**	--	Lump Sum	5,000
2	**Extraction Well/Well Pump System** • Deep well with pump • Shallow well with pump	 3 2	 7,200/system 7,200/system	 22,000 15,000
3	**Piping** from Extraction Wells to Equalization Tank	1,500 LF	23/LF	35,000
4	**Equalization Tank** (4 hr @ 40 gpm) • 10,000 gallons/tank (fiberglass) incl. fittings and freight cost	1 Tank	11,000	11,000
5	**Metals Pretreatment** • Costs incl. chemical feed pumps, chemical holding tanks, coagulation, flocculation, and clarification • Filter press (sludge dewatering) incl. 24 ft^3 press, feed pump, plate shifter	-- --	Lump Sum Lump Sum	64,000 45,000
6	**Air Stripping System** (40 gpm) • Incl. tower, blower, foundation, media, and electrical	1 System	Lump Sum	29,000
7	**Liquid Phase GAC Treatment Unit** • Incl. foundation, GAC canisters, instrumentation, and fittings	--	Lump Sum	58,000
8	**Vapor Phase GAC Treatment Unit** • Incl. foundation, GAC canisters, instrumentation, and fittings	--	Lump Sum	58,000
9	**Holding Tank** (60 min @ 40 gpm) • 2,500 gallon, instrumentation	1 tank	6,000	6,000
10	**Takeaway Pump**	2 pumps	3,200	6,400
11	**Piping** from Holding Tank to discharge point	1,000 LF	23/LF	23,000
12	**System Installation** (buildings etc.)	--	Lump Sum	200,000
13	**Electrical** (circuit breaker, panel, etc.)	--	Lump Sum	35,000
14	**System Start-Up**	400 hrs	45/hr	18,000
15	**Long-Term Monitoring** [b] • Initial investigations • Dedicated low-flow sampling equip. • New monitoring wells	 -- -- --	 Lump Sum Lump Sum Lump Sum	 29,000 26,000 9,500
			SUBTOTAL	695,000

TABLE B-1 Preliminary Estimate of Capital Costs For Alternative 6: Ground-Water Extraction with Air Stripping (Continued)

Item	Description	Quantity	Unit Cost ($)	Total Cost [a] ($)
16	**Mobilization/Demobilization, Construction Management, Permitting, and Site Services**		10%	70,000
17	**Design**		10%	70,000
18	**Contingency**		30%	209,000
19	**Closure Report**		Lump Sum	25,000
			TOTAL CAPITAL COST	1,069,000

(a) Cost estimates are based upon 1998 dollars. Total costs are rounded to the nearest $100 (or to the nearest $1,000 if greater than $10,000).

(b) Monitoring costs are conceptual and are subject to change. The scope of the monitoring program is being developed in a Long-Term Risk Monitoring Plan for Site 07.

TABLE B-2 Preliminary Estimate of Operation and Maintenance Costs For Alternative 6: Ground-Water Extraction With Air Stripping

Item	Description	Quantity	Unit Cost ($)	Total Cost (a) ($)
1	**Baseline and System Performance Monitoring** (Year 1) [b] • Sampling (labor/equip./ODC/DV/IDW) • Lab analyses • Reporting	 -- -- --	 Lump Sum Lump Sum Lump Sum	 210,000 12,000 60,000
2	**Liquid Phase GAC** • Incl. waste characterization, transportation, and treatment	--	Lump Sum	17,000
3	**Vapor Phase GAC system** • Incl. waste characterization, transportation, and GAC treatment	--	Lump Sum	43,000
4	**Water Sampling** • Incl. TCL VOC and QA/QC analysis, labor and equipment	--	Lump Sum	51,000
5	**Air Sampling** • Incl. TCL VOC and QA/QC analysis, labor and equipment	--	Lump Sum	36,000
6	**Metals Pretreatment** • Chemical Costs Potassium Permanganate NaOH (pH adjustment) Cationic polymer #1590C • System Maintenance (Metals Precipitation, Filter Press) incl. chemical preparation, sludge dewatering for 1 person • Sludge Disposal	 350 lb/yr 420 gal/yr 100 gal/yr 1.5 day/week --	 1.75/lb 2.6/gal 52/gal 60/hr Lump Sum	 700 1,100 5,200 38,000 6,300
7	**Utilities** (e.g., electricity)	--	Lump Sum	20,000
8	**Repair and Replacement**	--	Lump Sum	100,000
	BASELINE SUBTOTAL ANNUAL O&M COST			601,000
9	**Post-Baseline Monitoring** (Year 2-30) [b] • Sampling (labor/equip./ODC/DV/IDW) • Lab analyses • Reporting	 -- -- --	 Lump Sum Lump Sum Lump Sum	 70,000 4,000 20,000
10	**as items 2-8 above**	--	Lump Sum	319,000
	POST-BASELINE SUBTOTAL ANNUAL O&M COST			413,000

TABLE B-2 Preliminary Estimate of Operation and Maintenance Costs For Alternative 6: Ground-Water Extraction With Air Stripping (Continued)

Total 30-Year Present Worth

Capital Cost =	$ 1,069,000
Baseline O&M Cost = $ 601,000 Baseline Present Worth O&M Cost (5% rate) =	$ 573,000
Post-Baseline O&M Cost = $ 413,000 Post-Baseline Present Worth O&M Cost (5% rate) =	$ 5,956,000
	=======
TOTAL 30-YEAR PRESENT WORTH =	**$ 7,598,000**
	=======

(a) Cost estimates are based upon 1998 dollars. Total costs are rounded to the nearest $100 (or to the nearest $1,000 if greater than $10,000).
(b) Monitoring costs are conceptual and are subject to change. The scope of the monitoring program is being developed in a Long-Term Risk Monitoring Plan for Site 07.